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VOC Emissions from SOCMI Wastewater—
Background Information for
Proposed Standards

Emission Standards Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
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Office of Air Quality Planning and Standards
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ENVIRONMENTAL PROTECTION AGENCY

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VOC Emissions From SOCMI Wastewater

Prepared by:

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1. The proposed standards would regulate emissions of volatile organic compounds (VOC) emitted from wastewater generated by Synthetic Organic Chemical Manufacturing Industry (SOCMI) process units and are limited to emission points in the associated process unit's wastewater collection and treatment systems. These standards implement section 111 of the Clean Air Act based on the administrator's determination that VOC emissions from SOCMI cause, or contribute significantly to, air pollution that may reasonably be anticipated to endanger public health or welfare.

2. Copies of this document have been sent to the following Federal Departments: Labor, Health and Human Services, Defense, Office of Management and Budget, Transportation, Agriculture, Commerce, Interior, and Energy; the National Science Foundation; and the Council on Environmental Quality. Copies have also been sent to members of the State and Territorial Air Pollution Program Administrators; the Association of Local Air Pollution Control Officials; EPA Regional Administrators; and other interested parties.

3. The comment period for this document is 90 days from the date of publication of the proposed standards in the Federal Register. Ms. JoLynn Collins may be contacted at 919-541-5671 regarding the date of the comment period.

4. For additional information contact:

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5. Copies of this document may be obtained from:

U.S. EPA Library (MD-35)
Research Triangle Park, NC 27711
Telephone: 919-541-2777

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1.0 INTRODUCTION

1.1 BACKGROUND AND AUTHORITY OF STANDARDS

Standards of performance for new stationary sources are established under Section 111 of the Clean Air Act (42 U.S.C. 7411), as amended, herein referred to as the Act. Section 111 directs the Administrator to establish standards of performance for any category of new stationary source of air pollution that "causes, or contributes significantly to air pollution which may reasonably by anticipated to endanger public health or welfare."

The Act requires that standards of performance for stationary sources reflect "the degree of emission reduction achievable which (taking into consideration the cost of achieving such emission reduction, and any nonair quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated for that category of sources." The standards apply only to stationary sources, the construction or modification of which commences after regulations are proposed by publication in the Federal Register.

Standards of performance, by themselves, do not guarantee protection of health or welfare because they are not designed to achieve any specific air quality levels. Rather, they are designed to reflect the degree of emission limitation achievable through application of the best adequately demonstrated technological system of continuous emission reduction, with the cost of achieving such emission reduction, any nonair quality health and environmental impacts, and energy requirements being considered.

Promulgation of standards of performance does not prevent State or local agencies from adopting more stringent emission limitations for the same sources. States are free under Section 116 of the Act to establish even more stringent emission limits than those established under Section 111 or those necessary to attain or maintain the National Ambient Air Quality Standards (NAAQS) under Section 110. Thus, new sources may in some cases be subject to limitations more stringent than standards of performance under Section 111.

Although standards of performance are normally structured in terms of numerical emission limits, where feasible, alternative approaches are sometimes necessary. In some cases physical measurement of emissions from a new source may be impractical or exorbitantly expensive. Section 111(h) provides that the Administrator may promulgate a design or equipment standard in cases where it is not feasible to prescribe or enforce a standard of performance. For example, emissions of hydrocarbons from storage vessels for petroleum liquids are greatest during tank filling. The nature of the emissions--high concentrations for short periods during filling and low concentrations for longer periods during storage--and the configuration of storage tanks make direct emission measurement impractical. Therefore, equipment specification has been a more practical approach to standards of performance for storage vessels.

In addition, Section 111(j) authorizes the Administrator to grant waivers of compliance to permit a source to use innovative continuous emission control technology. In order to grant the waiver, the Administrator must find that the technology meets a specific set of conditions. Waivers may have conditions attached to assure that use of the innovative technology will not prevent attainment of any NAAQS. Any such condition will have the force of a performance standard. Finally, waivers have definite end dates and may be terminated earlier if the conditions are not met or if the system fails to perform as expected. In such a case, the source may be given up to 3 years to meet the standards with a mandatory progress schedule.

1.2 SELECTION OF STATIONARY SOURCES

The Clean Air Act amendments of August 1977 establish specific criteria to be used in determining priorities for regulating source categories. These are (1) the quantity of air pollutant emissions that each such category will emit, or will be designed to emit; (2) the extent to which each such pollutant may reasonably be anticipated to endanger public health or welfare; and (3) the mobility and competitive nature of each such category of sources and the consequent need for nationally applicable new source standards of performance.

After the source category has been chosen, the types of facilities within the source category to which the standard will apply must be determined. A source category may have several facilities that cause air pollution, and emissions from some of these facilities may vary from insignificant to very expensive to control. Economic studies of the source category and of applicable control technology may show that air pollution control is better served by applying standards only to the more severe pollution sources. For this reason, and because there is no adequately demonstrated system for controlling emissions from some types of facilities, standards often do not apply to all facilities at a source. For the same reasons, the standards may not apply to all air pollutants emitted. Thus, although a source category may be selected to be covered by a standard of performance, not all pollutants or facilities within that source category may be covered by the standards.

1.3 PROCEDURE FOR DEVELOPMENT OF STANDARDS OF PERFORMANCE

Standards of performance must (1) realistically reflect best demonstrated control practice; (2) adequately consider the cost, the nonair quality health and environmental impacts, and the energy requirements of such control; (3) be applicable to existing sources that are modified or reconstructed, as well as new installations; and (4) meet these conditions for all variations of operating conditions being considered anywhere in the country. The objective of a program for developing standards is to identify the best technological system of continuous emission reduction that has been adequately demonstrated.

As a part of the studies, hypothetical "model plants" are defined to provide a common basis for analysis. The model plant definitions, national pollutant emission data, and existing State regulations governing emissions from the source category are then used in establishing "regulatory alternatives." These regulatory alternatives are essentially different levels of emission control applicable to the source.

The EPA conducts studies to determine the impact of each regulatory alternative on the economics of the industry and on the national economy, on the environment, and on energy consumption. From several possibly applicable alternatives, the EPA selects the single most plausible regulatory alternative as the basis for a standard of performance for the source category under study. In the final phase of a project, the selected regulatory alternative is translated into a standard of performance, which, in turn, is written in the form of a Federal regulation. The Federal regulation, when applied to newly constructed plants, will limit emissions to the levels indicated in the selected regulatory alternative. The information acquired in the project is summarized in the Background Information Document (BID).

A "proposal package" is assembled and sent through the offices of EPA Assistant Administrators for concurrence before the proposed standard is officially endorsed by the EPA Administrator. After being approved by the EPA Administrator, the preamble and the proposed regulation are published in the Federal Register.

As a part of the Federal Register announcement of the proposed regulation, the public is invited to participate in the standard-setting process. The EPA invites written comments on the proposal and also holds a public hearing to discuss the proposed standards with interested parties. All public comments are summarized and incorporated into a second volume of the Bid. All information reviewed and generated in studies in support of the standard of performance is available to the public in a "docket" on file in Washington, DC.

Comments from the public are evaluated, and the standard of performance may be altered in response to the comments. The significant comments and the EPA's position on the issues raised are included in the "preamble" of a "promulgation package," which also contains the draft of the final regulation. The regulation is then subjected to another round of review and refinement until it is approved by the EPA Administrator. After the Administrator signs the regulation, it is published as a "final rule" in the Federal Register.

1.4 COST CONSIDERATIONS

Section 317 of the Act requires an economic impact assessment of any standard of performance established under Section 111. That assessment must include analyses of the costs of compliance, potential inflationary or recessionary effects, small business impacts, effects on consumer costs, and effects on energy usage. The analysis should include any costs associated with environmental effects of a regulation. For example, captured potential air pollutants may pose a solid waste disposal problem.

1.5 ENVIRONMENTAL IMPACTS

The EPA routinely prepares estimates of environmental impacts for regulatory actions under Section 111 of the Act.

This analysis is devoted to assessing potential environmental impacts of a standard and addresses both adverse and beneficial impacts. These impacts could occur in such areas as air and water pollution, increased solid waste disposal, and increased energy consumption. Estimates of the impacts of the NSPS are presented in a separate chapter of this Background Information Document.

1.6 IMPACT ON EXISTING SOURCES

Standards of performance under Section 111 of the Act apply to "new sources" which are defined as "any stationary source, the construction or modification of which is commenced" after the proposed standards are published. An existing source is redefined as a new source if "modified" or "reconstructed" as defined in the general provisions of Subpart A of 40 CFR Part 60.

2.0 INDUSTRY DESCRIPTION

The purpose of this chapter is to briefly describe and characterize the Synthetic Organic Chemical Manufacturing Industry (SOCMI). The chapter also discusses chemical production processes (CPP's) that are considered a part of SOCMI and describes waste and wastewater generation and handling. The discussion presented here is a summary of information in the Background Information Document for the Hazardous Organic NESHAP (HON)[1] and the reader is referred to that document for a more detailed discussion.

2.1 DESCRIPTION OF SOCMI

The SOCMI is one segment of the entire chemical industry and can be represented as an expanding system of production stages producing a multitude of organic chemicals from 11 basic chemicals. The first stage of the chemical industry which supplies the 11 basic chemicals includes refineries, natural gas plants, and coal tar distillation plants. The SOCMI consists of the remaining stages of this expanding production system. Within the SOCMI, the 11 basic chemicals are processed through one or more CPP's to produce intermediate and finished chemicals.

Within the SOCMi, there are often multiple means of manufacturing a given chemical. For example, the production of allyl alcohol is possible using three different raw materials. Also, an entire family of chemicals can often be produced sequentially from one chemical. Generally, there is a shift from high-volume production of SOCMI intermediates at the front end of the chemical family to low-volume production of finished chemicals (e.g., ethyl acrylate) at the farthest end of the chemical family. All of these production processes, regardless of capacity, are considered a part of SOCMI if they generate wastewater and would be subject to regulation under the NSPS for wastewater.

Organic chemicals are produced at a wide range of facilities, from large facilities manufacturing a few chemicals in large volumes, to smaller facilities manufacturing many different finished chemicals in smaller volumes. Facilities producing chemicals at the end of a chemical family are usually smaller operations that produce a variety of closely-related finished chemicals.

The products of the SOCMI are used in many different industrial markets. Many SOCMI chemicals serve as the raw materials for deriving non-SOCMI products such as plastics, synthetic rubbers, fibers, protective coatings, and detergents. Few SOCMI chemicals have direct consumer uses. The impacts analysis for this project considers only the production of SOCMI chemicals and does not cover the production of non-SOCMI products.

The SOCMI can be characterized geographically by identifying those states that should be analyzed to determine current levels of control and to establish baseline control requirements. A large percentage of the total number of process units in the SOCMI are found in only a few states, with Texas and Louisiana having the greatest number. Specifically, more than 70 percent of the SOCMI process units are located in only nine states. Forty of the 50 States have SOCMI process units, and 18 of the 40 States have less than 1 percent of the national total number of process units. Thus, it was not necessary to analyze all States for baseline control requirements.

2.2 CHARACTERIZATION OF THE INDUSTRY

In previous standards-setting programs, the EPA has characterized the SOCMI as a group of process units manufacturing or processing one or more chemicals included in a specific list. This approach has also been used for the NSPS analysis. There are a total of 735 chemical manufacturing processes subject to the proposed regulation. To make the scope of the NSPS as broad as possible, the list of chemicals proposed to be regulated under this rule is a composite list derived from several sources. These sources include: (1) "Industrial Organic Chemical Use Trees," EPA/ORD, October 1992; (2) Standards of Performance for Equipment Leaks of VOC in SOCMI, 40 CFR Part 60, Subpart VV; (3) Proposed Standards of Performance for SOCMI Reactor Processes, 55 FR 26953, June 29, 1990; (4) Standards of Performance for SOCMI Distillation Operations, 40 CFR Part 60, Subpart NNN; and (5) Standards of Performance for SOCMI Air Oxidation Processes, 40 CFR Part 60, Subpart III. The chemicals are listed in Appendix A of this document.

The SOCMI can be characterized in terms of production capacity and production rate where the difference between the two is capacity utilization. Without complete information for capacity utilization, capacity can be used as an indicator of rate. This information is important because emissions generally are closely tied to production rate. The characterization found that production capacities for process units range from less than 20 Gg/yr (22 million tpy) to greater than 600 Gg/yr (660 million tpy). The complete range of production volumes is included in the impacts evaluation.

2.3 REFERENCES

1. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Hazardous Air Pollutant Emissions From Process Units in the Synthetic Organic Chemical Manufacturing Industry--Background Information for Proposed Standards Volume 1A. Research Triangle Park, NC. November 1992. Chapter 3.

3.0 PROCESS DESCRIPTION AND EMISSION POINTS

Individual facilities within the SOCMI generate wastewater streams that contain organic compounds. These wastewaters are collected and treated in a variety of ways, some of which result in the emission of volatile organic compounds (VOC's) from the wastewater to the air. This chapter provides a discussion of potential VOC emissions from wastewater sources. Information in this chapter is primarily a summary of information contained in the Industrial Wastewater CTG[1] and the reader is referred to that document for a fuller discussion.

3.1 Sources of organic compound-containing wastewater

Organic compound-containing wastewater streams are generated by direct contact of water with organic compounds and by contamination of indirect contact wastewater through equipment leaks in chemical processing. Each of these two mechanisms are briefly described below.

3.1.1 Direct contact wastewater. Water may come into direct contact with organic compounds during a variety of different chemical processing steps, thus generating wastewater streams that must be discharged for treatment or disposal. Direct contact wastewater includes:

- Water used to wash impurities from organic compound products or reactants;
- Water used to cool or quench organic compound vapor streams;
- Condensed steam from jet eductor systems pulling vacuum

on vessels containing organic compounds;

- Water from raw material and product storage tanks;
- Water used as a carrier for catalysts and neutralizing agents (e.g., caustic solutions); and
- Water formed as a byproduct during reaction steps.

Direct contact wastewater is also generated when water is used in equipment washes and spill cleanups. This wastewater is normally more variable in flow rate and concentration than the streams listed above and may be collected in a way that is different from process wastewater.

3.1.2 Indirect contact wastewater. Wastewater streams generated by unintentional contact with organic compounds through equipment leaks are defined as "indirect contact" wastewater. Indirect contact wastewater may become contaminated as a result of leaks from heat exchangers, condensers, and pumps. These indirect contact wastewaters may be collected and treated differently from direct contact wastewaters. Pump seal water is often collected in area drains that tie into the process wastewater collection system. This wastewater is then combined with direct contact wastewater and transported to the wastewater treatment plant. Wastewater contaminated from heat exchanger leaks is often collected in different systems and may bypass some of the treatment steps used in the treatment plant.

3.2 Sources of air emissions

Wastewater streams are collected and treated in a variety of ways. Generally, wastewater passes through a series of collection and treatment units before being discharged from a facility. Many of these collection and treatment system units are open to the atmosphere and allow organic compound-containing wastewaters to contact ambient air, thus creating a potential for VOC emissions. The magnitude of VOC emissions is somewhat dependent on factors such as the physical properties of the

Table 3-1. EMISSION SOURCES IN WASTEWATER COLLECTION AND TREATMENT SYSTEMS

Drains
Manholes
Junction boxes
Lift stations
Trenches
Sumps
Weirs
Oil/water separators
Equalization or neutralization basins
Clarifiers
Aeration basins
Treatment tanks
Surface impoundments

pollutants, the temperature of the wastewater, and the design of the individual collection and treatment units. Climatic factors such as ambient temperature and wind speed and direction also affect VOC emissions at many wastewater collection and treatment units.

Collection and treatment schemes for wastewater are facility specific. The flow rate and organic compound composition of wastewater streams at a particular facility are functions of the processes used and influence the sizes and types of collection and treatment units needed. Table 3-1 lists potential sources of emissions in facility collection and treatment systems. The following sections briefly discuss each of these emission sources.

3.2.1 Drains. Waste streams from various sources throughout a given process are introduced into the collection system through process drains. Individual drains usually connect directly to the main process sewer line, but may drain to trenches, sumps, or ditches. Drains may be dedicated to a single piece of equipment or may serve several sources. Many drains are open to the atmosphere.

3.2.2 Manholes. Manholes provide access into process sewer lines for inspection and cleaning activities. They are normally placed at periodic distances along a sewer line and frequently occur where sewers intersect or change significantly in direction, grade, or sewer line diameter. Typically, manholes are covered with a heavy cast-iron plate that contains two or more holes.

3.2.3 Junction boxes. A junction box combines multiple wastewater streams into a single stream. Generally, the flow rate from the junction box is controlled by the liquid level within the junction box. Junction boxes are typically open, but may, for safety reasons, be closed and vented to the atmosphere.

3.2.4 Lift stations. Lift stations accept wastewater from one or more sewer lines and are usually the last collection unit before the treatment system. Lift stations collect and transport wastewater to the treatment system. Pumps designed to turn on and off in response to preset high and low liquid levels provide the necessary head pressure for wastewater transport. Lift stations are typically either open or closed and vented to the atmosphere.

3.2.5 Trenches. Trenches are used to transport wastewater from the point of discharge from a process to wastewater collection units such as junction boxes and lift stations. In older plants, trenches are often the primary mode of wastewater transportation in the collection system. Trenches are often interconnected throughout a process area and handle equipment pad water runoff, water from equipment wash downs and spill cleanups, and process wastewater discharges. Trenches are typically open or covered with grates.

3.2.6 Sumps. Sumps are used to collect and equalize wastewater flow from trenches before treatment. They are usually quiescent and open to the atmosphere. Sump size depends on the total flow rate of the incoming wastewater stream(s).

3.2.7 Weirs. Weirs act as dams in open channels. The weir face is usually aligned perpendicular to the bed and walls of a channel. Water from the channel may overflow the weir or may pass through a notch, or opening, in the weir face. Because of their configuration, weirs provide some control over the level and flow rate through the channel. Weirs may also be used for wastewater flow rate measurement.

Water overflowing a weir may proceed down stair steps that serve to aerate the wastewater thus increasing diffusion of oxygen into the wastewater. The increased oxygen may improve biodegradation processes which often follow weirs. However, this increased contact with air also accelerates the volatilization of organic compounds contained in the wastewater.

3.2.8 Oil/water separators. An Oil/water separator is often the first step in wastewater treatment, although they are also found in process areas. These units provide gravity separation and removal of oils, scum, and solids from the wastewater. Most separation occurs as the wastewater passes through a quiescent zone in the unit. Oils and scum with specific gravities less than water float to the top of the aqueous phase while heavier solids sink to the bottom. Some organic compounds in the wastewater partition into the oil phase and can be removed with the skimmed oil leaving the separator.

3.2.9 Equalization basins. Equalization basins are used to reduce fluctuations in wastewater temperature, flow rate, and organic compound concentrations. Equalization of wastewater flow rate results in more uniform effluent quality from downstream units and can benefit biological treatment performance by damping fluctuations of influent organic concentration and flow rate. This damping protects biological processes from upset or failure due to shock loadings of toxic or treatment-inhibiting compounds. Equalization basins normally use hydraulic retention time to ensure equalization of the wastewater effluent leaving the basin. However, some basins are equipped with mixers or surface aerators to enhance the equalization, accelerate wastewater cooling, or saturate the wastewater with oxygen before secondary treatment. Equalization basins are almost always open to the atmosphere. In some more recent wastewater collection and treatment systems, tanks, rather than basins, are used for equalization.

3.2.10 Clarifiers. The primary purpose of a clarifier is to separate solids from the wastewater through gravitational settling. Most clarifiers are equipped with surface skimmers to clear the water of floating oil deposits, grease, and scum. Clarifiers also have sludge raking arms that remove any accumulation of organic solids collected at the bottom of the tank. Clarifiers are designed to provide sufficient retention time for the settling and thickening of these solids.

3.2.11 Aeration basins. Biological waste treatment is normally accomplished through the use of aeration basins. Microorganisms require oxygen to carry out the biodegradation of organic compounds, which results in energy and biomass production. The aerobic environment in the basin is normally achieved with diffused air or by mechanical aeration. This aeration also serves to maintain the biomass in a well mixed regime. The performance of aeration basins is particularly affected by: (1) mass of organic compound per unit area of wastewater; (2) ambient temperature and wind patterns; (3) hydraulic retention time; (4) dispersion and mixing characteristics; (5) availability of sunlight energy; and (6) availability of essential microbial nutrients.

Three mechanisms affect organic compound removal in aeration basins: biodegradation, adsorption onto the sludge, and air emissions. Because these three mechanisms compete against each other, factors affecting biodegradation and adsorption mechanisms will also have an effect on air emissions.

Typically, aeration basins are equipped with aerators to introduce oxygen into the wastewater. The biomass uses this oxygen in the process of biodegrading organic compounds. However, aeration of wastewater also increases air emissions. Some plants have replaced open aeration basins with aerated tanks to reduce VOC emissions to the atmosphere.

3.2.12 Treatment tanks. Several different types of treatment tanks may be used in wastewater treatment systems. Tanks designed for pH adjustment typically precede the biological treatment step. In these tanks, the wastewater pH is adjusted, using acidic or alkaline additives, to prevent shocking the biological system downstream. Flocculation tanks are typically used to treat wastewater after biological treatment. Flocculating agents are added to the wastewater to promote formation or agglomeration of larger particle masses from the fine solids formed during biological treatment. In the clarifier, which usually follows the flocculation tanks in the system, these larger particles precipitate more readily out of the wastewater.

3.2.13 Surface impoundments. Surface impoundments are used for evaporation, polishing, storage before further treatment or disposal, equalization, leachate collection, and as emergency surge basins. They may be quiescent or mechanically agitated.

3.3 References

1 U.S. Environmental Protection AGency, Office of Air Quality Planning and Standards. Guideline Series Control of Volatile Organic Compound Emissions from Industrial

Wastewater. Research Triangle park, NC. Draft. September 1992. Chapter 3.

4.0 CONTROL TECHNOLOGY AND PERFORMANCE OF CONTROLS

There are two fundamentally different approaches to controlling VOC emissions from SOCMI wastewater sources. The first is a source reduction or waste minimization approach in which there is a reduction in the quantity of wastewater generated and/or a reduction in the VO content of the wastewater as a result of process modifications, modifications of operating practices, improved preventative maintenance activities, increased recycling, or segregation of VO containing waste streams. The second approach involves emission suppression and treatment of wastewater streams to remove organic compounds. The following paragraphs present a brief discussion of these two approaches. The discussions are derived primarily from information presented in the Industrial Wastewater CTG[1] and the reader is referred to that document for further details of the two approaches.

4.1 Waste minimization

Waste minimization may be achieved by source reduction or recycling. Source reduction involves the implementation of steps that reduce either the amount of wastewater generated or the amount of volatile organic matter contained in wastewater streams. Recycling includes recovery and/or reuse of potential wastes. There are several means of achieving the objectives of either of these waste minimization alternatives. Many waste minimization techniques are process specific and the degree of emission reduction achieved depends on the operating parameters of the individual process. The general approach to either source reduction or recycling includes three steps: (1) gathering baseline data on individual waste stream characteristics, (2) identifying and ranking sources for reduction, and (3) implementation of reduction/recycling alternatives. Selecting and implementing waste minimization activities can be enhanced by reviewing case studies and reports on pollution prevention or by obtaining information from State assistance programs, vendors, or consultants. Because of the site-specific nature of this approach, no estimates of emission control efficiency were made.

4.2 Suppression and treatment technologies

Under this emission control strategy, VOC emissions are reduced by a three-step program that includes: (1) suppression of emissions from collection and treatment system components up to the point of treatment; (2) treatment of wastewater streams to remove organic compounds: and (3) treatment of residuals such as oil phases, condensates, and sludges from nondestructive treatment operations.

4.2.1 Organic compound treatment technologies. There are three primary treatment technologies that are generally applicable and effective in reducing the VO content of wastewater streams. They are steam stripping, air stripping, and biological treatment. There are also several other methods of treatment that may be applicable to particular situations.

4.2.1.1 Steam stripping. Steam stripping is a proven technology that involves the fractional distillation of wastewater to remove organic compounds. Steam strippers may be operated in batch or continuous mode depending on the characteristics of the wastewater streams being treated. Steam stripping systems include enclosed wastewater collection and handling units up to the treatment unit, which includes a covered feed tank, a steam stripping tower, and controls on associated tank and condenser vents.

Although the VOC removal efficiency of steam strippers depends on the characteristics of both the steam stripper and the wastewater stream, steam stripping is the most universally applicable VOC removal technology for treating wastewater streams such as those generated by SOCMI processes. Data collected by EPA related to steam stripper performance for the treatment of wastewaters indicate organic compound removal efficiencies ranging from 76 percent to 99.9 percent. The Agency used that information in conjunction with model waste streams to develop equations to predict steam stripper removal efficiency as a function of the Henry's Law Constant for individual organic constituents of wastewater streams. These equations were then used to estimate VOC removal efficiencies and emission reductions for several industries. The four equations developed are as follows:

Henry's Law Constant (H) 25 °F range (atm ! m^3/mol)	Fraction Removed (F_r)
$H > 0.00105$	$F_r = 1.0$
$H < 3.3 \times 10^{-7}$	$F_r = 0$
$3.3 \times 10^{-7} \leq H \leq 8.9 \times 10^{-6}$	$F_r = 4.168 + 0.6430 * \log H$
$8.9 \times 10^{-6} \leq H \leq 1.05 \times 10^{-3}$	$F_r = 1.115 + 0.03865 * \log H$

4.2.1.2 Air stripping. Air strippers operate on the principle of vapor-liquid equilibrium. The technology is applicable to compounds with a wide range of volatilities and is most generally applicable to streams that contain dilute organic compound concentrations. Air strippers are most efficient in the removal of highly volatile, water insoluble compounds.

As with steam stripping, air strippers may be operated in either batch or continuous mode and operate as part of a system that includes enclosed wastewater collection and handling units up to the treatment unit. The overhead from the treatment unit including the feed tank is covered and vented to a control device, which may be an on-site boiler. Data collected by EPA indicate that the organic removal efficiency of air strippers ranges from about 58 to 99.9 percent for a range of organic compounds.

4.2.3 Biological treatment technology. Biological waste treatment is normally accomplished through the use of aeration basins. Microorganisms require oxygen to carry out the biodegradation of organic compounds. The aerobic environment is normally achieved by the use of diffused or mechanical aeration. Although the aeration is necessary to provide the oxygen necessary to maintain and promote biological degradation of the organic compounds, aeration also increases the liquid surface area exposed to ambient air. This action reduces both the liquid and gas phase resistance to mass transfer and thus causes an increase in air emissions relative to quiescent, flow-through type units.

Biological treatment in open basins is unlikely to result in the same level of VOC emission reduction that can be achieved by steam or air stripping. However, some biological treatment systems that make use of covered tanks vented to a control device may achieve emission reductions equivalent to that of strippers.

4.2.4 Other organic compound removal technologies. In addition to the three primary technologies for removing organics from wastewater, there are certain applications where other technologies may be more appropriate. These other technologies include chemical oxidation, carbon and ion exchange adsorption, membrane separation, and liquid-liquid extraction (or solvent extraction). These technologies rely on a variety of mechanisms to remove organic compounds from wastewater. They are used in different applications by facilities and may be effective at removing certain organic compounds.

4.3 Emissions suppression

VOC emissions from wastewater collection and treatment systems can be controlled either by hard piping or by enclosing the transport and handling system from the point of wastewater generation until the wastewater is treated to remove or destroy the organic compounds. Suppression techniques can be broken down into four categories: collection system controls, roofs, floating membranes, and air-supported structures. These devices and their associated VOC suppression efficiencies are discussed in detail in the Wastewater CTC Document.[2] Suppression of VOC emissions merely keeps the organic compounds in the wastewater until they reach the next potential VOC emission source. Therefore, these techniques are not effective unless the VOC emissions are suppressed until the wastewater reaches a treatment device where the organic compounds are either removed or destroyed.

Wastewater collection systems are made up of components such as drains, junction boxes, sumps, trenches, and lift stations. Other wastewater system components may include storage and treatment tanks, oil/water separators, and surface impoundments. Suppression controls can be applied to most of these components to reduce the potential for VOC emissions during wastewater collection. These controls involve the use of physical covers and water seals to minimize the contact between ambient air and the wastewater flowing through the component. Table 4-1 lists some of the controls that are applicable to collection system components. A complete description of each suppression control device can be found in the Wastewater CTC Document.[2]

Table 4-1. EMISSION SUPPRESSION CONTROLS FOR WASTEWATER COLLECTION SYSTEM COMPONENTS

Collection System Component	Suppression Control Options
Drains	Hard piping P-leg seals Seal pots
Junction boxes Sumps Lift stations	Gas-tight covers
Storage tanks Treatment tanks	Fixed roof Fixed roof with internal floating roof Fixed roof vented to control device Floating roof
Oil/water separators	Fixed roof Floating roof
Surface impoundments	Floating membrane covers Air-supported structures

4.4 Add-on controls

Add-on controls serve to reduce VOC emissions by destroying or extracting organic compounds from gas phase vent streams before they are discharged to the atmosphere. Add-on controls are applicable to vents associated with collection and treatment covers, such as drain covers, fixed roofs, and air-supported structures, and with organic compound removal devices, such as air strippers and steam strippers. Add-on controls for VOC emissions are classified into four broad categories: adsorption, combustion, condensation, and absorption. The type of add-on control best suited for a particular wastewater emission source depends on the size of the source and the characteristics of the wastewater in the source.

Combustion destroys the organic compounds in the gas stream by oxidation of the compounds primarily to carbon dioxide and water. Because essentially all organic compounds will burn, combustion add-on controls are applicable to all emission sources for which the organic vapors can be captured. Combustion add-on controls are thermal vapor incinerators, flares, boilers, and process heaters.

4.4.1 Carbon adsorbers. Carbon adsorbers make use of carbon that has been processed or "activated" to have a porous structure. In that state, carbon provides a large surface area upon which organic molecules can attach when an organic-containing gas stream is passed through the carbon bed. Carbon adsorbers are used in two main forms: fixed-bed and carbon canisters. In fixed-bed systems, when the carbon becomes saturated with organic material, it is regenerated to desorb the attached organic material. In most situations, fixed-bed systems make use of multiple carbon beds such that when one bed is in the process of regeneration, the other beds are on-line to adsorb organic material from a gas stream.

Carbon canisters are simple drums filled with activated carbon and equipped with inlet and outlet openings. Carbon canisters are used mostly with low volume gas streams with low organic concentrations. When the carbon in the canister become saturated, the canister is replaced and the carbon is either incinerated or recycled.

4.4.2 Thermal vapor incinerators. Thermal vapor incinerators consist of an enclosed chamber in which the oxidation process occurs. They may be refractory-lined with one or more discrete burners that premix organic vapor gas with combustion air and supplemental fuel or, they may use plate-type burners to produce a flame zone through which organic vapors pass. Packaged thermal vapor incinerators are commercially available in sizes ranging from 8 to 1,400 m^3/min (300 to 47,000 ft^3/min). When properly designed and operated, thermal vapor incinerators can achieve organic compound destruction efficiencies in excess of 98 percent.

4.4.3 Combination adsorption-incineration. In some cases, it is advantageous to combine carbon adsorption and thermal vapor incineration into a single control system. In these systems, the carbon adsorption unit serves to increase the organic concentration of the gas stream delivered to the thermal vapor incineration unit thus reducing the requirements for auxiliary fuel. These combination systems eliminate the need for solvent recovery in situations where recovery of the organics is not desirable or economically attractive.

Combination systems may be operated either continuously or on an intermittent basis. Packaged units are available in a wide range of capacities and operate at organic compound destruction efficiencies of 95 to 99 percent.

4.4.4 Catalytic vapor incinerators. Catalytic vapor incinerators are basically a flameless combustion process in which organic vapor streams are passed through a catalyst bed to promote oxidation at temperatures of 320 to 650 °C (600 to 1,200 °F). These incinerators may not be applicable for vapor streams with a high organic concentration because of the likelihood that the temperature limits would be exceeded thus leading to damage to the catalyst. In most installations, heat recovery is employed to heat the inlet vapor stream using heat from the hot exhaust gases. Organic compound destruction efficiencies in the range of 97 to 98 percent can be achieved by these systems.

4.4.5 Flares. Flares consist of an open combustion process in which oxygen for the combustion process is provided by ambient air around the flare. Mixing of air and organic vapors may be enhanced or "assisted" by injecting steam or air at the flare tip or by using a high-velocity nozzle. Flares are primarily used to burn waste gases from industrial processes such as those at petroleum refineries, blast furnaces, and coke ovens. Combustion efficiencies of up to 98 percent are achievable for assisted flares under most operating conditions.

4.4.6 Boilers and process heaters. Thermal destruction of organic vapors may be achieved in boilers and process heaters at many plants. The two processes currently being used for this application include: (1) premixing the organic vapor with a gaseous fuel and firing through an existing burner and (2) firing the organic vapor through a special retrofitted burner. Destruction efficiencies of 98 to 99 percent have been achieved by boilers and process heaters in this application.

4.4.7 Condensers. Condensation may be used on organic vapor streams to recover the organic material by converting the vapors to a liquid form. In most applications, the conversion is achieved by lowering the temperature, although increasing the pressure may also be used. The efficiency of condensers is highly dependent on the vapor pressure of the organic constituents in the vapor stream. Field measurements of efficiency have shown values ranging from 6 to 99.5 percent for different chemical compounds.

4.5 References

1 U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Guideline Series Control of Volatile Organic Compound Emissions from Industrial Wastewater. Research Triangle park, NC. Draft. September 1992. Chapter 4.

2. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Industrial Wastewater Volatile Organic Compound Emissions--Background Information for BACT/LAER Determinations. July 1990.

5. MODIFICATION AND RECONSTRUCTION

New Source Performance Standards (NSPS) apply to new, modified, and reconstructed (i.e., whose components are replaced to the extent that the source is, in effect, a new source) sources for which construction, modification, or reconstruction commenced (as defined under 40 CFR 60.2) after the date of proposal of the standards. Under Section 111 of the Clean Air Act, a source can be any building, structure, facility, or installation which emits or may emit any air pollutant. The sources to which each NSPS apply are defined in the standard as the "affected facility". Regulations governing modification and reconstruction are found in §60.14 and §60.15 of 40 CFR Part 60.

This chapter will discuss the selection of affected facility, and provide some general examples of the applicability of modification and reconstruction to affected facilities in the SOCMI.

5.1 SELECTION OF AFFECTED FACILITY

The Synthetic Organic Chemical Manufacturing Industry (SOCMI) is normally represented as a system of production stages that produces a wide range of organic chemicals. For the purpose of this NSPS, the SOCMI is defined as the production of organic chemicals, at a wide range of facilities, through different production stages known as process units. In the manufacture of organic chemicals, wastewater streams containing organic compounds may be generated from several sources. Organic compounds in the wastewater can volatilize and be emitted to the atmosphere from wastewater collection and treatment units if these units are open to the atmosphere. Potential sources of VOC emissions associated with wastewater collection and treatment include: individual drain systems, which are comprised of equipment such as open trenches, drains, sumps, manholes, junction boxes, lift stations, and weirs; surface impoundments; wastewater storage and/or treatment tanks; clarifiers; oil/water separators; and biological treatment units. At these points, VOC can be transferred from the wastewater to the air.

For the purpose of this NSPS, the affected facility is defined as each individual process unit, i.e., each SOCMI process unit which includes the equipment (e.g., mixers, reactors, distillation units) assembled and connected by pipes or ducts to produce, as intermediates or final products, one or more of the chemicals listed in the NSPS applicability section. This regulatory format avoids the problems associated with having multiple individual collection and treatment system components classified as affected facilities and also provides a definition that is sufficiently narrow in scope as not to totally eliminate the potential for existing sources becoming subject to NSPS through the modification and reconstruction provisions. In addition, this format will allow the plant to make modifications to update wastewater collection and treatment systems as necessary to enhance their performance without causing the system to be classified as an affected facility under this NSPS.

5.2 MODIFICATION

Regulations governing modification determination for the purposes of applying NSPS are contained in §60.14 of the General Provisions to 40 CFR Part 60. With certain exceptions, any physical or operational change to an existing process unit that would increase the emission rate from that process unit of any pollutant covered by the standard would be considered a modification within the meaning of Section 111 of the Clean Air Act. The key to determining if a change is considered a modification is whether actual emissions to the atmosphere from the process unit have increased on a mass per time basis (kg/h) as a result of the change. Changes in emission rate may be determined by the use of emission factors, by material balances, by continuous monitoring data, or by manual emission tests in cases where the use of emission factors does not clearly demonstrate that emissions do or do not increase. Under the current regulations, an emission increase from one process unit may not be offset with a similar emission decrease at another process unit to avoid becoming subject to NSPS. If an existing facility is determined to be modified, it becomes an affected facility, subject to the standards of performance for the pollutant or pollutants that have increased due to modification. All emissions, not just the incremental increase in emissions, of the pollutants that have increased from the affected facility must be in compliance with the applicable standards.

Under the General Provisions to 40 CFR Part 60, certain physical or operational changes are not considered to be modifications even though emissions may increase as a result of the change (see 40 CFR 60.14(e)). The following physical or operational changes are not considered to be modifications, even though they may cause emissions to increase:

1. Routine maintenance, repair, and replacement (e.g., lubrication of mechanical equipment; replacement of pumps, motors, and piping; cleaning of equipment);

2. An increase in production rate without a capital expenditure (as defined in 40 CFR 60.2);

3. An increase in the hours of operation;

4. Use of an alternative fuel or raw material if, prior to proposal of the standard, the existing facility was designed to accommodate that alternative fuel or raw material;

5. The addition or use of any system or device whose primary function is to reduce air pollutants, except when an emission control system is replaced by a system determined by EPA to be less environmentally beneficial; and

6. Relocation or change in ownership of the existing facility.

An owner or operator of an existing facility who is planning a physical or operational change that may increase the emission rate of a pollutant to which a standard applies shall notify the appropriate EPA regional office 60 days prior to the change, as specified in 40 CFR 60.7(a)(4).

The following discussion identifies some possible changes to process unit operations used in SOCMI which might be considered modifications. The magnitude of the industry covered and the complexity of the manufacturing process permit only a general discussion of these possible changes. Furthermore, the list of potential modifications for process units is not exclusive. The following general types of process modifications are identified for SOCMI process units:

1. Feedstock, catalyst, or reactant substitution;

2. Process equipment changes; and

3. Combinations of the above.

<u>Feedstock, catalyst, or reactant substitution</u> is dictated by economics and the level of availability of the feedstock, catalyst, or reactant. Depending upon the specific process, change in feedstock or catalyst may require substantial capital investment to modify the process to accommodate the change. The magnitude of the capital investment may prohibit feedstock or catalyst substitution for many chemicals.

Many of the chemicals produced in the SOCMI can be manufactured from two or more different feedstocks. For example, cyclohexane can be manufactured using either phenol or cyclohexanol as the feedstock. In most cases, however, feedstock substitution would likely require both equipment and process changes.

Reactant substitutions within the SOCMI process units is also a likely change that could constitute a modification. For example, for many chemicals, the potential exists to substitute air for pure oxygen or a chemical oxidant as a reactant or vice versa. Changing to an air oxidation process may be an advantage because (1) air is readily available and (2) expensive corrosion-resistant materials are not required compared to the use of chemical oxidants. However, there may be major disadvantages in changing from an oxygen or chemical oxidation process to an air oxidation process, including a substantial reduction in plant capacity, a large increase in the reactor-related process vent stream flowrate (i.e., increased VOC emissions), and an altered product mix. Either of these (i.e., using pure oxygen or the oxygen in the air) may be substituted for chemical oxidation processes as well. Reactant substitutions of this type may increase process unit VOC emissions to the atmosphere and as a result may constitute a modification (unless the fixed capital expenditure exceeds 50 percent of the fixed capital cost required to construct a comparable new facility, in which case it would be considered reconstruction).

Process equipment changes may also constitute modifications. Examples of potential modifications are replacing a fixed-bed reactor with a fluidized-bed reactor, increasing the plant capacity by increasing the size of the reactor or adding additional reactors, and changing the product recovery system (e.g., from an absorber to a condenser). Such changes might be considered modifications since they can result in increased VOC emissions. Again, capital expenditures may be a factor in determining whether it is modification or reconstruction.

A combination of the changes described above would be chosen in any given situation with the decision based on the most advantageous economics for the site-specific conditions. The combination of changes might be considered a potential modification if they resulted in an increase in emissions. The most common combinations are plant expansions or simultaneous changes in feedstock and catalyst as described earlier. Other combinations however are possible.

The enforcement division of the appropriate EPA regional office will make the final determination as to whether an existing facility is modified and, as a result, subject to the standards of performance of an affected facility.

5.3 RECONSTRUCTION

An existing facility may become subject to NSPS if it is reconstructed. Reconstruction is defined in 40 CFR 60.15 as the replacement of the components of an existing facility to the extent that (1) the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost required to construct a comparable new facility and (2) it is technically and economically feasible for the facility to meet the applicable standards. Because EPA considers reconstructed facilities to constitute new construction rather than modification, reconstruction determinations are made irrespective of changes in emission rates.

The purpose of the reconstruction provisions is to discourage the perpetuation of an existing facility for the sole purpose of circumventing a standard that is applicable to new facilities. Without such a provision, all but vestigial components (such as frames, housing, and support structures) of the existing facility could be replaced without causing the facility to be considered a "new" facility subject to NSPS. If the facility is determined to be reconstructed, it must comply with all of the provisions of the standards of performance applicable to that facility. If an owner or operator of an existing facility is planning to replace components and the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost of a comparable new facility, the owner or operator must notify the appropriate EPA regional office 60 days before construction of the replacement commences, as required under 40 CFR 60.15(d).

The enforcement division of the appropriate EPA regional office will make the final determination as to whether an existing facility is reconstructed and, as a result, subject to the standards of performance of an affected facility.

5.4 REFERENCES FOR CHAPTER 5

1. The U.S. Environmental Protection Agency. Code of Federal Regulations. Title 40, Chapter I, Subpart A, part 60. Washington, D.C., Office of the Federal Register.

2. The U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, N.C. Distillation Operations in Synthetic Organic Chemical Manufacturing - Background Information For Proposed Standards. EPA-450/3-83-005a. December 1983.

6.0 METHODOLOGY FOR ESTIMATING BASELINE AND CONTROLLED ORGANIC EMISSIONS

This chapter presents a general discussion of the methodology used to develop estimates of volatile organic compound (VOC) emissions from wastewater operations within the SOCMI source category. The chapter includes: (1) an explanation of the assumptions used to establish the regulatory baseline for the impact analyses, (2) descriptions of the control options used in the impact analyses, and (3) the techniques applied to estimate both baseline and controlled emissions.

6.1 BASELINE CHARACTERIZATIONS

The EPA has recently been involved with two regulatory efforts that relate to air emissions from wastewater streams at SOCMI facilities: development of the Industrial Wastewater Control Techniques Guidelines (CTG) document,[1] and development of the Hazardous Organic NESHAP (HON).[2] In support of those efforts, the EPA conducted a survey of SOCMI facilities under the authority of Section 114 of the Clean Air Act. In that survey, owners and operators of facilities within nine corporations completed questionnaires asking for information on wastewater streams from SOCMI production processes. The questionnaires included information on the flow rate and concentration of individual hazardous air pollutants (HAP's) and total VOC's in each wastewater stream. The Agency used the survey responses to establish a data base (referred to herein as "the SOCMI data base") with data for a total of 461 wastewater streams generated by 110 SOCMI process units at 25 plant sites. The survey responses provided sufficient information to allow the characterization of flow rate, VO concentration, emission potential, and strippability of individual wastewater streams.

VO concentration refers to the volatile organic concentration of a wastewater stream as measured by EPA Method 25D. The regulatory alternatives considered for this NSPS are based on controlling wastewater streams with a VO concentration, as measured by Method 25D, above specified trigger or action levels. The EPA calculated values for VO concentration for the SOCMI wastewater streams from reported values of the concentrations of individual volatile organic constituents. In that calculation, each reported individual constituent concentration in a waste stream is multiplied by an estimated fraction of the total that would be detected by EPA Reference Method 25D and summed across all constituents. This procedure can be expressed in an equation as follows:

$$VO = \sum_i (VOC_i * fm_i)$$

Where,

VO = Volatile organic concentration as measured by EPA Method 25D;

VOC_i = Total concentration of volatile organic compound i; and

fm_i = The fraction of total volatile organic compound i measured by EPA Method 25D, predicted for compounds of interest using a theoretical analysis.

This VO concentration calculation allows analyses to be made of the SOCMI data base that involves control of those wastewater streams with VO concentrations above specified levels.

6.2 BASELINE AND CONTROLLED EMISSIONS ESTIMATES

The environmental and other impacts of alternative standards are evaluated by establishing a baseline to which all regulatory alternatives are compared. For the SOCMI secondary sources NSPS, VOC emissions at affected facilities in the absence of the NSPS represent baseline. As discussed in Chapter 1, air emissions from SOCMI secondary sources are already covered by air emission regulations at what is likely to be a large fraction of facilities. The HON applies to SOCMI wastewater sources that contain HAP's in concentrations above the trigger level. In addition, some SOCMI wastewater sources may be covered by either the NESHAP for vinyl chloride or the NESHAP for benzene waste operations. Sources that would be subject to this NSPS include process units that have HAP concentrations in their wastewater below the cutoff level for the HON and process units for which the wastewater contains VOCs that are not classified as HAPs. This category of sources has the potential to be a significant source of VOC air pollutant emissions and is the primary focus of the NSPS.

Baseline emissions for SOCMI wastewater streams are calculated using the information and methodology presented in the BID for the HON as previously referenced. Baseline emissions are calculated as uncontrolled emissions using emission factors developed as a part of the analysis of waste stream data for the HON. That analysis involved development of emission factors for individual organic constituents found in SOCMI wastewater streams based on information in the SOCMI data base.[3] Those emission factors (or fractions emitted, fe) were developed using theoretical mass transfer equations to calculate emission factors for individual organic chemical constituents in a wastewater stream as the stream passes through individual wastewater collection and treatment units. The calculated individual values for fraction emitted were used to establish a relationship between fraction emitted and Henry's Law constant for individual organic constituents. That relationship is used to estimate the fraction emitted for constituents that do not have a value calculated for fraction emitted based on theoretical considerations.

Uncontrolled VOC emissions from typical wastewater collection and treatment systems are estimated as the sum of the products of the fraction emitted and the individual constituent concentration of a waste stream. The calculations are made using the following equation:

$$E = \sum_i (Q * VOC_i * fe_i)$$

Where:

E = Annual VOC emissions from the wastewater stream, (Mg/yr),

Q = Annual wastewater stream flow (calculated based on the reported stream flow in lpm and full time operation for 351 days/yr), (M^3/yr),

VOC_i = Concentration of constituent i, (ppm),

fe_i = Fraction emitted for constituent i.

Annual emissions from individual units can be calculated by summing across all wastewater streams generated by the unit. Annual emissions from a plant can be calculated by summing across all units at the plant.

Calculations are also made to estimate total VOC emissions after the controls required by the NSPS have been installed. For those calculations, emission control was assumed to be accomplished by processing the waste streams through a steam stripper. The fraction of VOC that would be removed by steam stripping was estimated by first predicting the VOC removal efficiency of a model steam stripper for each individual volatile organic constituent and then summing across all constituents. This analysis can be expressed in an equation as follows:

$$FR = \sum_{i} (VOC_i * fr_i)$$

Where,

FR = The fraction of total VO removed from a wastewater stream due to steam stripping, or the fractional reduction in emission potential;

VOC_i = The VOC concentration of compound i;

fr_i = The fraction of compound i removed by steam stripping from a wastewater stream.

Estimates of steam stripper efficiency for individual compounds are based on the predicted efficiency of the design steam stripper as described in Chapter 4 of the Industrial Wastewater CTG.[4]

6.3 REFERENCES

1. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Guideline Series Control of Volatile Organic Compound Emissions from Industrial Wastewater. Research Triangle Park, NC. Appendix B. Draft. September 1992.

2. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Hazardous Air Pollutant Emissions from Process Units in the Synthetic Organic Chemical Manufacturing Industry -- Background Information for Proposed Standards Volume 1C: Model Emission Sources. EPA-453/D-92-016c. Research Triangle Park, NC. p. 5-10 - 5-29. November 1992.

3. Reference 1.

4. Reference 1. Chapter 4.

7.0 NATIONWIDE ENVIRONMENTAL AND ENERGY IMPACTS

As part of the rulemaking process, EPA estimates the nationwide impacts of various regulatory alternatives in terms of primary air pollutant impacts, cost impacts, and other environmental and energy impacts. These estimates represent the impacts of applying emission controls on all emission points nationwide that are required to apply additional control as a part of complying with the NSPS. These estimated impacts are factored into decisions regarding selection of the most appropriate regulatory alternative to serve as the basis for a proposed standard.

In estimating nationwide impacts, EPA estimates the quantity of emissions from the affected industry in the absence of national standards to serve as a baseline emission level, and then calculates potential emission reductions under alternative emission control scenarios (i.e., regulatory alternatives). Studies are then made to estimate impacts of these alternatives on the environment, the economics of the industry and the nation, and on energy consumption. Collectively, these estimates represent the impacts of the standard. For this NSPS, impact estimates were made on both a model plant basis and on a national basis. The impacts of regulatory alternatives for emission control include emission reductions, costs, impacts to other environmental media, and changes in energy usage.

7.1 BASIS FOR IMPACTS ESTIMATION

Impacts of the regulatory alternatives for the SOCMI secondary sources NSPS were estimated as an increment to the impacts calculated for the hazardous organic NESHAP (HON). In effect, the level of emissions after implementation of the HON serves as the baseline for the NSPS.

The estimated nationwide impacts of the NSPS are based on detailed analyses of the SOCMI data base described in Chapter 6.0 of this document. For the purposes of the analysis, the EPA assumed that the information in that data base is representative of new process units that will be subject to control by the NSPS. The analysis examined each individual wastewater stream in the SOCMI data base to determine if emission controls would be required by the HON. The determination was based on the HON criteria for new sources, which differ from the criteria for existing sources. The estimated emission reductions and costs of controlling these waste streams were then calculated using the procedures discussed in Chapter 6.

Following the examination of the wastewater streams based on the HON criteria, each wastewater stream not requiring control by the HON was reexamined to identify those streams that would require control by the NSPS. Emission reductions and costs of controlling those streams represent the impacts of the NSPS. NSPS impacts were analyzed in this way for a series of 5 regulatory alternatives with progressively more stringent criteria for wastewater streams that require control.

7.2 ESTIMATION OF CONTROLLED EMISSIONS

The control technology evaluated for wastewater collection and treatment operations was a steam stripper followed by an air emissions control device (i.e., the emission potential of the wastewater stream is reduced by removing the organics from the wastewater prior to management in units that result in air emissions). Steam stripping achieves variable emission reductions depending on the volatility and strippability of the organics (e.g., VOC or HAP's) in the wastewater. For the purpose of estimating the control impacts, it was assumed that the air emissions control device was an existing combustion device such as a thermal vapor incinerator or process heater.

Control impacts for wastewater collection and treatment operations were estimated on a facility basis. Control costs were evaluated based on the total facility-wide wastewater flow as related to production rate. Emission reductions, a function of strippability and the quantity of wastewater treated, were estimated for each wastewater stream.

7.3 ESTIMATION OF NSPS IMPACTS

7.3.1 Approach to Impacts Estimation

The NSPS will require control of all wastewater streams that contain VOC's in excess of a specified trigger level and, in some cases, that also have a stream flow rate above a specified minimum value. Thus, the NSPS will require SOCMI plants to control some wastewater streams that do not require control under the HON or other air rules. Many of the plants that are affected by the NSPS will also be affected by the HON and are anticipated to be required to install a steam stripper for treating those wastewater streams regulated by the HON. In estimating cost impacts of the NSPS, EPA assumed that those plants affected by the NSPS that are also affected by the HON would increase the capacity (or operating hours) of the steam stripper required under the HON to handle the additional wastewater streams that would require control under the NSPS. The cost associated with the NSPS for those plants is the difference in costs for two steam strippers, one with the capacity and operating hours to handle wastewater streams regulated by the HON and the other with the capacity and operating hours to handle wastewater streams regulated by both the HON and the NSPS. Plants affected by the NSPS that are not affected by the HON are assumed to install a new steam stripper to comply with the NSPS.

The Agency evaluated two different approaches for projecting the results of the impacts estimates for the SOCMI data base to nationwide impacts. In the first, nationwide impacts are estimated as an increment to the impacts previously calculated for the HON. In the second approach, nationwide impacts are estimated based on the ratio of the total quantity of wastewater generated by the facilities in the SOCMI data base and the total quantity of wastewater generated nationwide by SOCMI plants. The analyses were completed for 5 regulatory alternatives under consideration as a basis for the NSPS. Each alternative is defined by a specified action level defined in terms of a VO concentration and stream flow. All wastewater streams having a VO concentration and stream flow at or above the action level would be subject to an NSPS based on that alternative. In addition, under each alternative, streams with a VO concentration above a specified maximum level also would be subject to the rule regardless of the stream flow rate. Action levels for each of the 5 regulatory alternatives are listed in Table 7-1.

Table 7-1. NSPS Regulatory Alternatives

Alternative No.	VO Concentration (ppmw)	Flow Rate Cutoff (lpm)	Maximum VO Concentration[a] (ppmw)
Baseline[b]			
1	1,000	10	10,000
2	800	5	10,000
3	500	1	10,000
4	100	1	10,000
5[c]	0	0	

[a] Wastewater streams with a VO content above this level must be controlled regardless of flow rate.
[b] Baseline is the level of control that would be applied to new sources without the NSPS.
[c] Alternative 5 is total industry control (i.e., control all wastewater streams).

7.3.2 Results of Impacts Estimation

7.3.2.1 Incremental approach based on HON impacts. Under this approach, nationwide impacts for the NSPS are estimated as an increment applied to the HON impacts that were estimated as part of the regulatory development effort in support of the HON. To obtain the incremental impacts, an analysis consisting of three steps was performed as follows:

1. Using the HON impacts as a baseline, incremental emissions and cost impacts for each of the five NSPS regulatory alternatives were calculated using the SOCMI data base.

2. Using the SOCMI data base analysis, the percentage increase in emission reductions and costs for each NSPS alternative relative to the emission reductions and costs for the HON were calculated.

3. The percentage changes in emissions and costs were applied to the estimated industry-wide emissions and costs for new plants as calculated for the HON. (The HON impacts for new plants in the fifth year is estimated at 16 percent of the total impacts in the fifth year.)

The results of steps 1 and 2 of this approach are presented in Table 7-2. That table, based on analyses of the SOCMI data base, shows the estimated VOC emission reduction and costs for complying with the HON and the VOC emission reductions and costs of complying with each of the five NSPS regulatory alternatives.

Table 7-2. Emission Reductions and Costs for HON and NSPS*

Regulatory Alternative	VOC Emission Reductions (Mg/yr)		Percent Increase	Total Annual Costs ($$10^6$)		Percent Increase
	HON	NSPS		HON	NSPS	
1	5,626	7,007	24.55%	$5.32	$6.00	12.78%
2	5,626	7,112	26.41%	$5.32	$6.18	16.17%
3	5,626	7,340	30.47%	$5.32	$6.92	30.08%
4	5,626	7,589	34.89%	$5.32	$8.29	55.83%
5	5,626	8,053	43.14%	$5.32	$13.34	150.75%

*Based on SOCMI data base.

Table 7-3. Nationwide Impacts of NSPS Options

Regulatory Alternatives	Emission Reduction (Mg/yr)	Total Annual Costs ($)	Cost Effectiveness ($/Mg)	Incremental Cost Effectiveness ($/Mg)
1	14,534	$1,022,556	$70	--
2	15,635	$1,293,233	$83	$246
3	18,038	$2,406,015	$133	$463
4	20,655	$4,466,165	$216	$787
5	25,539	$12,060,150	$472	$1,555

The percentage increase in both emission reduction and cost are also presented for each regulatory alternative.

The results of step 3 are presented in Table 7-3, which shows calculated nationwide VOC emission reductions and costs attributable to the NSPS under each of the regulatory alternatives. The basis for these numbers is the estimated nationwide fifth year impacts estimated for the wastewater portion of the HON which are as follows:

VOC emission reduction - 370,000 Mg/yr

Total annual cost - $50,000,000

Total capital Investment - $140,000,000

Sixteen percent of these estimated total nationwide emission reductions and cost are attributable to new sources of emissions constructed during the first 5 years of the rule. Fifth year impacts of the NSPS were estimated by escalating the new source impacts for the HON by the calculated fractional increases shown in Table 7-2.

Equation 1 is an example calculation for estimating the emission reduction associated with regulatory alternative 1 using the above steps.

$$E_r = 0.16 \; x \; 370{,}000 \; x \; 0.2455 = 14{,}534 \; Mg/yr \qquad (1)$$

Where:

E_r = emission reduction (Regulatory alternative 1 in Table 7-3),

0.16 = percentage of estimated total HON emissions reduction attributable to new sources,

370,000 = Estimated nationwide emission reduction from wastewater sources due to the HON, and

0.2455 = Fractional increase in emission reduction for the NSPS relative to the HON (Regulatory Alternative 1 in Table 7-2).

Table 7-4. Emission Reductions and Costs for NSPS Alternatives*
In the Fifth Year After Promulgation

Regulatory Alternative	Controlled Wastewater Flow (lpm)	Fraction Wastewater Controlled	Emission Reductions (Mg/yr)	Total Annual Costs ($$10^6$)	Cost Effectiveness ($/Mg)	Emission Red. Per Unit Flow (Mg/yr/lpm)
1	1,309	0.043	1,382	0.696	$504	1.056
2	1,675	0.055	1,487	0.874	$588	0.888
3	3,221	0.105	1,714	1.609	$938	0.532
4	6,049	0.197	1,964	2.982	$1,518	0.325
5	20,289	0.661	2,428	8.165	$3,363	0.120

*Based on SOCMI data base.

Table 7-5. Nationwide Impacts of NSPS Options
in the Fifth Year after Promulgation

Regulatory Alternatives	Emission Reduction (Mg/yr)	Total Annual Costs ($)	Cost Effectiveness ($/Mg)	Incremental Cost Effectiveness ($/Mg)
1	11,678	$5,886,000	504	-
2	12,560	$7,385,000	588	1700
3	14,365	$13,474,000	938	3373
4	16,465	$24,994,000	1518	5486
5	20,399	$68,602,000	3363	11085

7.3.2.2 Wastewater flow rate approach. The results of the impacts estimates using this approach for each of the five regulatory alternatives are presented in Table 7-4. That table shows the emission reduction estimated to be achieved by each regulatory alternative, the estimated total annual costs of control for each regulatory alternative, and the cost effectiveness of controlling emissions under each alternative. In addition, the quantity of wastewater controlled by each alternative as well as the percentage of total wastewater flow controlled under each alternative are also calculated. These figures serve as part of the basis for projecting the results of the SOCMI data base analysis to nationwide impacts. The emission reduction per unit of controlled wastewater flow is also shown.

Estimates of nationwide impacts of the NSPS use the information in Table 7-4 (based on the analysis of the SOCMI data base) coupled with recent estimates of (1) industry growth over the next five years and (2) the nationwide quantity of wastewater generated by SOCMI process units. As a part of the analysis of the HON,[1] separate estimates of the impacts on new and existing process units were developed. Estimation of the impacts on new facilities were based on estimated industry growth. Based on current economic trends in the industry, a figure of 3.5 percent per year was derived as an estimate of growth over the next 5 years.[2]

The nationwide annual rate of wastewater generation at SOCMI facilities was estimated as a part of the analysis for the Control Techniques Guideline (CTG) document for industrial wastewater.[3] In that document, the nationwide wastewater flow for the organic chemicals, plastics, and synthetic fibers (OCPSF) industry was estimated at 1,374,800 liters per minute (lpm). Elsewhere in the documentation for that study,[4] it was estimated that SOCMI facilities account for about 99.5 percent of the OCPSF industry. The EPA assumes that these values represent conditions within the SOCMI for the purposes of the NSPS impacts calculations.

Using the nationwide flow estimates, the estimated industry growth, and the results of the analysis of the SOCMI data base, the EPA derived estimates of the NSPS impacts in the fifth year after promulgation. At a growth rate of 3.5 percent per year, the total growth over 5 years would be approximately 18.8 percent. When applied to the estimated nationwide wastewater flow of 1,374,800 lpm, the increase in wastewater generation in the fifth year is estimated as:

$$Q = 1{,}374{,}800 \ x \ 0.188 \ x \ 0.995 = 257{,}170 \ lpm$$

Using that value, the nationwide emission reduction for each regulatory alternative is estimated using the following equation:

$$E = Q \ x \ fq \ x \ er$$

Where:

E = Estimated annual nationwide VOC emission reduction, (Mg/yr),

Q = Estimated growth in wastewater generation in the first 5 years, (lpm),

fq = The fraction of wastewater requiring control under the NSPS (from Table 7-4),

er = Annual VOC emissions reduction per unit of flow (from Table 7-4), (Mg/yr/lpm).

The nationwide costs of each regulatory alternative are estimated as the product of the emission reduction and the cost effectiveness calculated for each alternative as presented in Table 7-4. Both the estimated emission reductions and estimated costs of each regulatory alternative are presented in Table 7-5.

7.3.2.3 Combined results. The two approaches to estimating impacts yield widely different nationwide impacts and cost effectiveness for the 5 regulatory alternatives. The Agency's goal in pursuing two approaches was to have two sets of results that would be mutually supportive of one another. That goal was not achieved although the Agency believes that both approaches are legitimate means of estimating impacts. Because the Agency did not identify a sound basis for selecting one set of estimates over the other, rather than discard one set of results, the Agency chose to average the results of the two approaches. Table 7.6 presents the calculated averages for nationwide emission reduction and total annual costs of the two approaches. Cost-effectiveness, in units of $/Mg are also shown in that table. All of the nationwide cost figures in Table 7-6 include the estimated cost associated with the reporting and recordkeeping burden that would be imposed by a regulation. That cost was estimated to be $859,436 as described in the Information Collection Request and supporting statement for the rule.[5] Estimated total annual capital cost of each regulatory alternative over the first five years of the rule were also calculated as the average of the values derived by each of the

Table 7-6 Estimated NSPS Impacts Based on Averaging

Regulatory Alternative	Emission Reduction (Mg/yr) SOCMI	HON	Average	Total Annual Costs ($) SOCMI	HON	Average	Average Cost Effectiveness ($/Mg)
1	11,678	14,534	13,106	$6,745,000	$1,882,000	$4,313,500	$329
2	12,560	15,635	14,097	$8,244,000	$2,153,000	$5,198,500	$369
3	14,365	18,038	16,202	$14,333,000	$3,265,000	$8,799,000	$543
4	16,465	20,655	18,560	$25,853,000	$5,326,000	$15,589,500	$840
5	20,399	25,539	22,969	$69,461,000	$12,920,000	$41,190,500	$1,793

Table 7-7 Total Capital Costs Based on Averaging of Two Methods

Regulatory Alternative	Fifth Year Capital Costs ($) SOCMI	HON	Average
1	$1,901,941	$3,218,880	$2,560,411
2	$2,432,128	$4,114,880	$3,273,504
3	$4,285,258	$7,250,880	$5,768,069
4	$8,087,457	$13,684,160	$10,885,809
5	$23,769,213	$34,126,400	$28,947,807

two approaches. These costs are presented in Table 7.7.

In both approaches to impacts estimation, the cost analysis assumes a mix of individual plant costs depending on whether or not a plant is affected by both the NSPS and the HON or is affected only by the NSPS. The plant by plant cost analysis for plants in the SOCMI data base indicate that the average NSPS compliance costs for plants installing a new steam stripper are approximately a factor of 3 higher than the costs for plants that use the same steam stripper for compliance with both the HON and the NSPS. The analysis also shows that approximately 12 percent of plants would need to install new steam strippers to comply with the NSPS.

7.4 OTHER ENVIRONMENTAL AND ENERGY IMPACTS

Some adverse effects on air quality and other environmental media and increased energy requirements are associated with the use of emission control devices such as steam strippers to control emissions from wastewater operations. Impacts associated with air quality and other media include emissions of NO_x and CO and the generation of solid waste and water pollution. This section presents a brief discussion of estimated environmental and energy impacts associated with steam stripping wastewater streams. The discussion is based on the analysis undertaken in development of the HON[6], which is briefly summarized here.

7.4.1 Secondary Air Pollution Impacts

Secondary air impacts associated with steam stripping can occur from two sources: (1) combustion of fossil fuels for steam and electricity generation, and (2) handling or combustion of recovered organics. The analysis for the HON assumed proper handling of recovered organics by either recycling to the process or by combustion. The impacts of off-site electricity generation were not estimated in the analysis and, as a result, the calculated secondary air impacts are associated only with the generation of steam for the steam stripping operations. Based on industry-wide average fuel usage, secondary air pollution impacts were estimated for both NO_x and CO.

7.4.2 Other Impacts

Steam stripping also has impacts on other environmental media and on energy consumption. Following are brief discussions of these other impacts.

7.4.2.1 Water Pollution Impacts. Steam strippers remove organics from wastewater, thus improving the quality of wastewater being discharged to a wastewater treatment plant or

POTW. Therefore, their use has an overall positive impact on water pollution.

7.4.2.2 Solid and Hazardous Waste Impacts. Solid and hazardous waste can be generated from recovered organics, solids removal, and control system vent emissions. Additional solid waste may be generated in situations where system vent emissions are collected on sorbent media that are not regenerated. For the NSPS, solid waste impacts are estimated to be negligible.

7.4.2.3 Energy Impacts. Fossil fuel used to generate steam for steam stripping systems can reduce available nonregenerable resources such as coal, oil and natural gas. The impacts are partially offset if recovered organics are recycled or used as supplemental fuel.

7.4.3 Impacts Estimates

For the purpose of estimating secondary environmental and energy impacts for the NSPS alternatives, it was assumed that the secondary environmental and energy impacts are directly proportional to the emission reduction achieved using the steam stripping control options. Using the analysis from the HON, the magnitude of each secondary impact per unit of emission reduction was calculated. These values were then used to calculate secondary environmental and energy impacts of the NSPS alternatives. Estimated impacts for the HON are as follows:[7]

- Carbon monoxide emissions 100 Mg/yr
- NO_x emissions 800 Mg/yr
- Electricity usage 13×10^6 kw-hr/yr
- Natural gas usage 3×10^9 Btu/yr
- Steam usage $3,000 \times 10^9$ Btu/yr.

These figures are used to derive a value for the magnitude of each impact per unit of emission reduction by dividing each by the estimated total emission reduction of 370,000 Mg/yr. The resulting values are:

- Carbon monoxide emissions .00027 Mg/yr

- NO_x emissions .00216 Mg/yr
- Electricity usage .0000351 x 10^6 kw-hr/yr
- Natural gas usage 3.00000811 x 10^9 Btu/yr
- Steam usage .00811 x 10^9 Btu/yr.

Nationwide impacts for the NSPS alternatives are obtained by multiplying the unit impact values by the estimated emission reduction for each alternative as estimated in Table 7-6. The results of these calculations are provided in Table 7-8.

Table 7-8. Other Environmental and Energy Impacts in the Fifth Year after Promulgation

Regulatory Alternative	Carbon Monoxide (Mg/yr)	Nitrogen Oxides (Mg/yr)	Electricity Usage (10^6 Kw-hr/yr)	Natural Gas Usage (10^9 Btu/yr)	Steam Usage (10^9 Btu/yr)
1	3.53	28.23	0.459	0.106	105.85
2	3.80	30.36	0.493	0.114	113.87
3	4.38	35.02	0.569	0.131	131.33
4	5.01	40.11	0.652	0.150	150.41
5	6.20	49.59	0.806	0.186	185.96

7.5 REFERENCES

1. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Hazardous Air Pollutant Emissions from Process Units in the Synthetic Organic Chemical Manufacturing Industry -- Background Information for Proposed Standards Volume 1A, 1B, and 1C. Research Triangle Park, NC. November 1992.

2. Reference 1. Volume 1A: National Impacts Assessment. p. 5-3.

3 U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Guideline Series Control of Volatile Organic Compound Emissions from Industrial Wastewater. Research Triangle Park, NC. Appendix B. Draft. September 1992.

4. Memorandum from Cris Bagley, Radian, to Penny Lassiter, EPA/CPB, "Development of National Impacts for the Industrial Wastewater CTG." April 4, 1991.

5. ICR and Supporting Statement. Review Draft. U.S. Environmental Protection Agency, Research Triangle Park, NC. April 1994.

6. Reference 1, Volume 1A: National Impacts Assessment. p. 5-10 - 5-18.

7. Reference 5 with updated values supplied by U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC. 1994.

8.0 ENHANCED MONITORING

The 1990 Clean Air Act Amendments require that new EPA regulations include monitoring strategies that incorporate the concepts of enhanced monitoring. The purpose of enhanced monitoring is to provide a means for major sources to demonstrate that the affected facility is in continuous compliance with the standards. Enhanced monitoring requirements are intended to ensure that monitoring data can be used both to determine compliance with each applicable standard and to determine the existence of enforceable violations.

The preferred implementation of enhanced monitoring is the use of a continuous emission monitor system (CEMS). However, there are cases where CEMS are not technically feasible or economically practical. In those cases, the EPA's approach is generally to require the continuous monitoring of specified operating parameters that are established as being directly related to emission control performance. This chapter discusses enhanced monitoring as it applies to the NSPS for SOCMI wastewater.

8.1 ENHANCED MONITORING FOR CONTROL DEVICES

The EPA considered three monitoring options for control devices: (1) the use of CEMS to measure total VOC; (2) the use of CEMS for surrogate compounds such as total hydrocarbons (THC) as surrogate for total VOC; and (3) the continuous monitoring of control device operating parameters. The first two of these options were found not to be reasonable alternatives for this rule.

Although continuous emission monitors for total VOC are currently available, they are not universally applicable within the SOCMI wastewater source category. Existing CEMS for total VOC operate either by flame ionization detection (FID), photoionization detection (PID), non-dispersive infrared (NDIR) absorption, or other detection principles that respond to VOC levels. In most cases, VOC monitors provide only a measure of the relative concentration of a mixture of organics rather than quantification of organic species.[1] This characteristic leads to the use of VOC CEMS as a relative indicator of emissions rather than as a conventional emissions monitor. VOC CEMS would only provide a quantitative measure of emissions in situations where total VOC is represented by a single chemical compound or compounds that generate equal responses by the monitoring instrument. Such situations are unlikely at SOCMI process units. SOCMI wastewaters generally have multiple chemical constituents at variable concentrations, thus, even CEMS that use gas chromatography, which are normally not usable if the number of organic compounds exceeds five, may not be appropriate for this application.[2] In light of these considerations, the implementation of CEMS to measure VOC emissions were determined to be unreasonable costly. This conclusion is reinforced by demonstrations that have shown parametric monitoring to be less costly than CEMS but equally effective in indicating continuous compliance. Consequently, owners, or operators that use control devices such as incinerators or condensers to comply with the proposed standards may use CEMS where applicable to demonstrate continuous compliance, if they find it reasonable to do so. However, parameter monitoring is also allowed.

Temperature is an acceptable parameter to monitor for both incinerators and condensers. Incinerator monitoring would measure the combustion zone temperature in thermal incinerators or the temperature upstream and downstream of the catalyst bed in catalytic incinerators. Condenser monitoring would involve temperature monitoring of the vapor exhaust stream.

Because CEMS are generally not applicable for determining compliance for many SOCMI wastewaters, and because there generally is a control device parameter such as temperature that is a suitable indicator of control device performance, and because temperature monitors are much less costly than CEMS, parameter monitoring is judged to be the most appropriate means of demonstrating compliance with the control device standards. In many cases, such monitoring does not impose any additional burden on the owner or operator because may operating parameters are already routinely monitored for other purposes. To demonstrate continuous compliance, a control device must maintain parameter values within the ranges that represent compliance. These ranges are established during an initial performance.

8.2 MONITORING OF WASTEWATER TREATMENT DEVICES

The primary technique by which owners and operators are expected to comply with the SOCMI wastewater NSPS is by treating the wastewater with a steam stripper followed by a control device. Regulatory provisions in the NSPS describe design and operating characteristics of a steam stripper. These design and equipment standards require the installation, calibration, operation, and maintenance of continuous monitors in accordance with manufacturers specifications. The monitors are required to continuously record: (1) the mass rate of wastewater entering the stripper, (2) the mass rate of steam entering the stripper, and (3) the wastewater column feed temperature. Acceptable values for these parameters, indicating proper operation of the treatment device, are established during the initial performance test or according to design specifications in the regulation.

These parameters are routinely monitored in the industry to ensure proper operation of the steam stripper. Therefore, continuous compliance for a steam stripper is assured without any additional enhanced monitoring burden on the industry.

8.3 ENHANCED MONITORING OF TANKS

Emission controls for tanks are based on the use of covers, which is an equipment requirement rather than a performance standard. In some situations, the use of a fixed roof on a tank may be adequate and in other cases a floating roof vented to a control device may be needed. When tanks are vented to an external control device, enhanced monitoring of the control device may be required as discussed above. There are, however, no continuous or enhanced monitoring alternatives for either fixed or floating roofs. Tank monitoring requirements include initial and periodic inspections coupled with adequate equipment maintenance.

8.4 ENHANCED MONITORING OF CONTAINERS

The control of emissions from containers is based on the use of covers and the use of a submerged fill pipe for container loading. These control techniques are equipment requirements rather than performance standards. Consequently, there are no enhanced monitoring alternatives for containers.

8.5 ENHANCED MONITORING OF CLOSED VENT SYSTEMS

Monitoring requirements for closed vent systems includes an initial performance test to ensure that the system is maintained under negative pressure. This is followed by monthly inspections to confirm that all openings in the system that were closed during the performance test remain closed.

To ensure continuous compliance with the NSPS requirements for no detectable leaks, closed vent systems are monitored initially with a portable hydrocarbon detector. After that, monitoring consists of annual visual inspections of ductwork, piping, covers, and connections for evidence of visible defects. There are also requirements for prompt repair of any defects found.

If the closed vent system includes a bypass line, a flow indicator must be installed, calibrated, maintained, and operated in accordance with manufacturer's instructions to provide a record of emission point gas stream flow at least once every 15 minutes. Alternatively, bypass lines may be sealed is a closed position and visually inspected to ensure that they are maintained in the closed condition.

8.6 REFERENCES

1. Performance specification 101 - Performance Specifications for Volatile Organic Compound Continuous Emission Monitoring Systems in Stationary Sources, 58 FR 54693, October 22, 1993.

2. Performance Specification 102 - Performance Specification for Gas Chromatographic Continuous Emission Monitoring Systems in Stationary Sources, 58 FR 54694, October 22, 1993.

9.0 CONTROL COST ESTIMATES

This chapter presents a brief discussion of the procedures used to estimate the nationwide implementation costs of an NSPS for SOCMI secondary sources. Cost impacts include total capital costs, total annual costs, and average cost effectiveness (i.e., the cost per megagram of pollutant removed). Average cost effectiveness is computed by dividing the national annual cost by the national emission reductions relative to baseline. Cost estimates for controlling emissions from wastewater operations are based on facility-wide control because this is general industry practice. The costs of wastewater treatment are based on the use of steam strippers. Steam stripping systems contain several components including feed tank, heat exchanger, steam stripping column, condenser, overheads receiver, and an emission control device. As has been discussed elsewhere in this BID, the impacts of the NSPS are calculated as an increment to the impacts calculated for the HON and steam stripping costs are calculated as the difference between the cost of a steam stripper with the capacity to handle the wastewater streams that require control under the HON and a stripper with the higher capacity needed to treat the combined wastewater streams that require treatment under either the HON or the NSPS. Designing and costing steam strippers to handle multiple wastewater streams at a facility provides an economy of scale compared to the control of individual wastewater streams. A brief summary of the approach to designing and costing a steam stripping system is presented here. Details of the procedures can be found in the BID for the HON.[1]

9.1 STEAM STRIPPER DESIGN

Steam stripping systems are designed in several different configurations depending on a number of site-specific circumstances. However, the components of most systems are fairly uniform and include a feed tank, a feed/bottoms heat exchanger, steam stripping column, vent lines, condenser system, and ancillary pumps. The following paragraphs present a brief description of the components of a steam stripping system. Additional design details are available in the BID for the HON.[2]

9.1.1 Feed tank

A controlled sewer system or hard piping between the point of generation and the feed tank can be used to prevent air emissions from wastewater prior to a steam stripping operation. The feed tank, which is covered and vented to a control device, serves to collect and condition wastewater for conveyance to the steam stripper. Feed tanks are sized to provide the retention time needed to allow for variations in wastewater stream flow rate and to allow for any needed conditioning of the wastewater. Feed tanks are also used for phase separation when the waste stream consists of both organic and aqueous phases and in these cases must provide adequate retention time for phase separation to occur. Solids tend to settle out in the feed tank and are removed by periodic cleaning.

9.1.2 Steam stripper

From the feed tank, wastewater is pumped through the feed/bottoms heat exchanger where it is preheated by the heated effluent stream and then pumped into the top of the steam stripping column. Steam is sparged into the stripper at the bottom of the column. Uncondensed steam and vaporized organics flow out the top of the column and the effluent leaving the bottom is pumped through the feed/bottoms heat exchanger to heat the feed stream. The cooled effluent may be routed to a wastewater treatment plant or discharged to a permitted outfall or a publicly owned treatment works (POTW).

9.1.3 Emissions control

Steam stripper systems include vent lines to transport gaseous organics, water vapor, and noncondensables between system elements such as the stripper column and recovery device, recovery device and feed tank, and feed tank and combustion device. All vent lines are controlled by either a combustion device or product recovery device. Combustion device alternatives include thermal or catalytic incinerators, flares, boilers, or process heaters. Product recovery devices include condensers, carbon adsorbers, or absorbers. Openings in the steam stripper system for pressure relief, venting, or maintenance access are sealed unless in use.

9.1.4 Product recovery

Product recovery from a steam stripper is normally achieved by a condenser system. In some cases, a secondary, refrigerated condenser is needed to increase recovery efficiency. Recovered organics are either recycled to the process or combusted in an incinerator, boiler, or process heater. Noncondensibles in the stripper overhead are routed to a control device such as a carbon adsorber, boiler, process heater, or incinerator.

9.1.5 Stripper efficiency

The efficiency with which a steam stripper removes organic compounds from a wastewater stream is highly dependent on the volatility of the individual organic compounds and may range from 0 to more than 99 percent. Removal performance also depends on the degree of contact between the steam and wastewater. The degree of contact is determined by the design and operating parameters of the system such as: (1) the height and diameter of the column; (2) the selection of either trays or packing as the contacting media; and (3) operating parameters such as steam-to-feed ratio, column temperature, and wastewater pH. Removal efficiency of a steam stripper is lower for wastewater streams with organic concentrations below a threshold of about 50 to 100 ppm. Above that threshold, efficiency is relatively constant but declines rapidly below the threshold. Steam stripper efficiency is higher for chlorinated compounds than for non-chlorinated compounds.

9.1.6 Applicability

Steam stripping is most applicable to treating wastewaters with organic compounds that are highly volatile and have a low solubility in water. The VOC's that have low volatility tend to volatilize less readily and thus are not easily stripped out of the wastewater by steam. Similarly, VOC's that are very soluble in water tend to remain in the wastewater and also are not easily stripped out by steam. Oil, grease, and solids content as well as pH of a wastewater stream also affect the applicability of steam stripping to a particular wastewater stream. High levels of oil, grease, and solids often create operational problems for the system and high or low pH may produce equipment corrosion. Problems such as these can often be avoided by modifications to the equipment design or by wastewater conditioning prior to treatment.

9.2 STEAM STRIPPER COSTS

This section presents a brief overview of the approach to estimating steam stripper costs. Additional details of the approach are available in the BID for the HON.[3]

9.2.1 Design considerations

A primary determinant of steam stripper capital costs is the size of the stripper which is a function of the design throughput of the system and the design removal efficiency. Column diameter is a function of design throughput and column height is a function of design removal efficiency. Steam stripper annual costs are a function of the annual steam requirement which is a function of both the steam-to-feed ratio and the annual wastewater throughput. For highly corrosive wastewater streams, capital costs may be increased because of the need to fabricate the system using stainless steel rather than carbon steel.

9.2.2 Capital costs

Total capital investment is calculated as the sum of the purchased equipment cost, direct installation costs, and indirect installation costs. Purchased equipment costs is comprised of the cost of basic equipment, auxiliary piping and equipment, instrumentation, freight, and taxes. Direct installation costs include such elements as electrical wiring, insulation, equipment support and erection, and equipment painting. Indirect installation costs include engineering, construction and field expense, construction fee, start-up and testing, and contingency. Total capital investment may also include costs for buildings, off-site facilities, land, working capital, and yard improvements. Equations for estimating the capital costs of the various components of a steam stripping system and for estimating the total capital investment of a system are described in the BID for the HON.

9.2.3 Annual costs

Total annual cost is the total of all costs incurred to operate the steam stripper system over an entire year and include both direct and indirect charges. Direct annual costs consist of normal operating expenses such as utilities, labor and maintenance activities. Indirect operating costs include overhead and capital recovery, which is calculated based on a projected operating life of the equipment and anticipated interest rates. Where organic materials are recovered from the steam stripping system and a benefit is derived, total annual costs are adjusted downward by the value of the recovered materials. If no cost-effective use can be made for the recovered organics, an additional disposal cost may be incurred.

Factors for estimating direct and indirect annual costs and the capital recovery factor are presented in the BID for the HON.

9.3 REFERENCES

1. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Hazardous Air Pollutant Emissions from Process Units in the Synthetic Organic Chemical Manufacturing Industry—Background Information for Proposed Standards Volume 1A, 1b, and 1C. Research Triangle Park, NC. November 1992.

2. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Hazardous Air Pollutant Emissions from Process Units in the Synthetic Organic Chemical Manufacturing Industry—Background Information for Proposed Standards Volume 1B Control Technologies. Research triangle Park, NC. p. 2-33 - 2-42. November 1992.

3. Reference 2. p. 3-31 - 3-40.

4. Reference 2. p. 3-33 - 3-34.

5. Reference 2. p. 3-38 - 3-40.

Appendix A

List of SOCMI Chemicals

Appendix A
List of SOCMI Chemicals

Chemical Name[a]	CAS Number[b]
Acenaphthene	83329
Acetal	105577
Acetaldehyde	75070
Acetaldol	107891
Acetamide	60355
Acetanilide	103844
Acetic acid	64197
Acetic anhydride	108247
Acetoacetanilide	102012
Acetone	67641
Acetone cyanohydrin	75865
Acetonitrile	75058
Acetophenone	98862
Acetyl chloride	75365
Acetylene	74862
Acetylene tetrabromide	
Acrolein	107028
Acrylamide	79061
Acrylic acid	79107
Acrylonitrile	107131
Adipic acid	124049
Adiponitrile	111693
Alcohols, C-11 or lower, mixtures	---
Alcohols, C-11 or higher, mixtures	---
Alizarin	72480
Alkyl anthraquinones	008
Alkyl naphthalene sulfonates	---
Alkyl naphthalenes	---

Chemical Name[a]	CAS Number[b]
Allyl alcohol	107186
Allyl bromide	
Allyl chloride	107051
Allyl cyanide	109751
Aluminum acetate	
Aluminum formates	
Aminobenzoic acid (p-)	1321115
Aminoethylethanolamine	111411
Aminophenol sulfonic acid	0010
Aminophenol (p-)	123308
Amino 3,4,6-trchlorophenol	123308
Ammonium acetate	
Ammonium thiocyanate	
Amylene	513359
Amylenes, mixed	---
Amyl acetates	628637, 123922
Amyl alcohol (n-)	71410
Amyl alcohol (tert-)	71410
Amyl alcohols (mixed)	71410
Amyl chloride (n-)	543599
Amyl chlorides (mixed)	
Amyl ether	
Amyl mercaptans	110667
Amyl phenol	1322061
Amylamines	110587
Aniline	62533
Aniline hydrochloride	142041
Anisidine (o-)	90040
Anisidine (p-)	29191524

Chemical Name[a]	CAS Number[b]
Anisole	100663
Anthracene	120127
Anthranilic acid	118923
Anthraquinone	84651
Azobenzene	103333
Barium acetate	
Benzaldehyde	100527
Benzamide	55210
Benzene	71432
Benzenedisulfonic acid	98486
Benzenesulfonic acid	98113
Benzenesulfonic acid C_{10-16}-alkyl derivatives, sodium salts	68081812
Benzidine	
Benzil	134816
Benzilic acid	76937
Benzoguanamine	
Benzoic acid	65850
Benzoin	119539
Benzonitrile	100470
Benzophenone	119619
Benzotrichloride	98077
Benzoyl chloride	98884
Benzoyl peroxide	
Benzyl acetate	140114
Benzyl alcohol	100516
Benzyl benzoate	120514
Benzyl chloride	100447
Benzyl dichloride	98873
Benzylamine	100469

Chemical Name[a]	CAS Number[b]
Benzylideneacetone	
Biphenyl	92524
Bisphenol A	80057
Bis(Chloromethyl)Ether	542881
Brometone	
Bromobenzene	108861
Bromoform	75252
Bromonaphthalene	27497514
Butadiene (1,3-)	106990
Butadiene and butene fractions	---
Butane	106978
Butanes, mixed	---
Butanediol (1,4-)	110634
Butenes, mixed	---
1-Butene	106989
2-Butene	25167673
Butyl acetate (n-)	123864
Butyl acetate (sec-)	
Butyl acetate (tert-)	
Butyl acrylate (n-)	141322
Butyl alcohol (n-)	71363
Butyl alcohol (sec-)	78922
Butyl alcohol (tert-)	75650
Butyl benzoate	
Butyl chloride (tert-)	
Butyl hydroperoxide (tert-)	75912
Butyl mercaptan (n-)	
Butyl mercaptan (tert-)	
Butyl methacrylate (n-)	
Butyl methacrylate (tert-)	

Chemical Name[a]	CAS Number[b]
Butyl phenol (tert-)	
Butyl toluene (tert-)	
Butylamine (n-)	109739
Butylamine (s-)	13952846
Butylamine (t-)	75649
Butylbenzene (tert-)	
Butylbenzoic acid (p-tert-)	98737
Butylbenzyl phthalate	85867
Butylene glycol (1,3-)	107880
Butylenes (n-)	
2-Butyne-1,4-diol	110656
Butyraldehyde (n-)	123728
Butyric acid (n-)	107926
Butyric anhydride (n-)	106310
Butyrolacetone	96480
Butyronitrile	109740
Calcium acetate	
Calcium propionate	
Caproic acid	
Caprolactam	105602
Carbaryl	63252
Carbazole	86748
Carbon disulfide	75150
Carbon tetrabromide	558134
Carbon tetrachloride	56235
Carbon tetrafluoride	75730
Cellulose acetate	9004357
Chloral	75876
Chloranil	
Chloroacetic acid	79118

Chemical Name[a]	CAS Number[b]
Chloroacetophenone (2-)	532274
Chloroaniline (m-)	108429
Chloroaniline (o-)	95512
Chloroaniline (p-)	106478
Chlorobenzaldehyde	35913098
Chlorobenzene	108907
Chlorobenzoic acid	118912, 535808, 74113
Chlorobenzotrichloride (o-)	2136814, 2136892, 5216251
Chlorobenzotrichloride (p-)	2136814, 2136892, 5216251
Chlorobenzoyl chloride (o-)	1321035
Chlorobenzoyl chloride (p-)	1321035
2-Chloro-1,3-butadiene (Chloroprene)	126998
Chlorodifluoroethane	25497294
Chlorodifluoromethane	75456
2-Chloro-4-(ethylamino)-6-(isopropylamino)-S-triazine	1912249
Chlorofluorocarbons	
Chloroform	67663
Chlorohydrin	
Chloronaphthalene	25586430
Chloronitrobenzene (m-)	121733
Chloronitrobenzene (o-)	88733
Chloronitrobenzene (p-)	100005
Chlorophenol (m-)	108430

Chemical Name[a]	CAS Number[b]
Chlorophenol (o-)	95578
Chlorophenol (p-)	106489
Chlorosulfonic acid	7790945
Chlorotoluene (m-)	108418
Chlorotoluene (o-)	95498
Chlorotoluene (p-)	106434
Chlorotrifluoroethylene	
Chlorotrifluoromethane	75729
Choline chloride	
Chrysene	218019
Cinnamic acid	
Citric acid	77929
Cobalt acetate	
Copper acetate	
Cresol and cresylic acid (m-)	108394
Cresol and cresylic acid (o-)	95487
Cresol and cresylic acid (p-)	106445
Cresols and cresylic acids (mixed)	1319773
Crotonaldehyde	4170300
Crotonic acid	3724650
Cumene	98828
Cumene hydroperoxide	80159
Cyanamide	
Cyanoacetic acid	372098
Cyanoformamide	
Cyanogen chloride	506774
Cyanuric acid	108805
Cyanuric chloride	108770
Cyclohexane	110827
Cyclohexane, oxidized	68512152

Chemical Name[a]	CAS Number[b]
Cyclohexanol	108930
Cyclohexanone	108941
Cyclohexanone oxime	100641
Cyclohexene	110838
Cyclohexylamine	108918
Cyclooctadiene	29965977
Cyclooctadiene (1,3-)	111784
Cyclooctadiene (1,5-)	111784
Cyclopentadiene (1,3-)	
Cyclopropane	75194
Decahydronaphthalene	91178
Decanol	112301
Decyl alcohol	
Diacetone alcohol	123422
Diacetoxy-2-Butene (1,4-)	0012
Diallyl isophthalate	
Dially phthalate	
Diaminobenzoic acids	27576041
Diaminophenol hydrochloride	137097
Dibromomethane	74953
Dibutanized aromatic concentrate	---
Dibutoxyethyl phthalate	
Dichloroaniline (mixed isomers)	27134276
Dichlorobenzene (p-)	106467
Dichlorobenzene (m-)	541731
Dichlorobenzene (o-)	95501
Dichlorobenzidine (3,3'-)	91941
1,4-Dichlorobutene	110576
3,4-Dichloro-1-butene	64037543
Dichloro-2-butenes	

Chemical Name[a]	CAS Number[b]
Dichlorodifluoromethane	75718
Dichlorodimethylsilane	
Dichloroethane (1,2-) (Ethylene dichloride) (EDC)	107062
Dichloroethyl ether (bis(2-chloroethyl)ether)	111444
Dichloroethylene (1,2-)	540590
Dichlorofluoromethane	75434
Dichlorohydrin (a-)	96231
Dichloromethyl ether	
Dichloronitrobenzenes	
Dichloropentanes	
Dichlorophenol (2,4-)	120832
Dichloropropane (1,1-)	
Dichloropropene (1,3-)	542756
Dichloropropene/dichloropropane (mixed)	
Dichlorotetrafluoroethane	1320372
Dichloro-1-butene (3,4-)	760236
Dichloro-2-butene (1,4-)	764410
Dicyanidiamide	
Dicyclohexylamine	101837
Dicyclopentadiene	
Diethanolamine (2,2'-Iminodiethanol)	111422
Diethyl phthalate	
Diethyl sulfate	64675
Diethylamine	109897
Diethylaniline (2,6-)	579668
Diethylaniline (N,N-)	
Diethylbenzene	25340174
Diethylene glycol	111466
Diethylene glycol dibutyl ether	112732
Diethylene glycol diethyl ether	112367

Chemical Name[a]	CAS Number[b]
Diethylene glycol dimethyl ether	111966
Diethylene glycol monobutyl ether acetate	124174
Diethylene glycol monobutyl ether	112345
Diethylene glycol monoethyl ether acetate	112152
Diethylene glycol monoethyl ether	111900
Diethylene glycol monohexyl ether	112594
Diethylene glycol monomethyl ether acetate	629389
Diethylene glycol monomethyl ether	111773
Difluoroethane (1,1-)	75376
Di-n-heptyl-n-nonyl undecyl phthalate	
Dihydroxybenzoic acid (Resorcylic acid)	27138574
Diisobutylene	25167708
Diisodecyl phthalate	26761400
Diisononyl phthalate	28553120
Diisooctyl phthalate	27554263
Diisopropyl amine	
Diketene	674828
Dimethyl acetamide	
Dimethylbenzidine (3,3'-)	119937
Dimethyl ether	115106
Dimethylformamide (N,N-)	68122
Dimethylhydrazine (1,1-)	57147
Dimethyl phthalate	
Dimethyl sulfate	77781
Dimethyl sulfide	75183
Dimethyl sulfoxide	67685
Dimethyl terephthalate	120616
Dimethylamine	124403
Dimethylaminoethanol (2-)	108010
Dimethylaniline (N,N)	121697

Chemical Name[a]	CAS Number[b]
Dinitrobenzenes (NOS)[c]	25154545
Dinitrobenzoic acid (3,5-)	99343
Dinitrophenol (2,4-)	51285
Dinitrotoluene (2,3-)	
Dinitrotoluene (2,4-)	121142
Dinitrotoluene (2,6-)	606202
Dinitrotoluene (3,4-)	
Dioctyl phthalate	117817
Dioxane (1,4-) (1,4-Diethyleneoxide)	123911
Dioxolane (1,3-)	646060
Diphenyl methane	101815
Diphenyl oxide	101848
Diphenyl thiourea	102089
Diphenylamine	122394
Dipropylene glycol	110985
Di(2-methoxyethyl) phthalate	
Di-o-tolyguanidine	97392
Dodecandedioic acid	693232
Dodecene (branched)	
Dodecene (n-)	25378227
Dodecyl benzene (branched)	123013
Dodecylbenzene, nonlinear	---
Dodecylbenzene sulfonic acid	27176870
Dodecylbenzene sulfonic acid, sodium salt	25155300
Dodecylmercaptan (branched)	
Dodecyl phenol (branched)	121158585
Dodecylaniline	28675174
Dodecylbenzene (n-)	121013
Dodecylphenol	27193868
Epichlorohydrin (1-chloro-2,3-epoxypropane)	106898

Chemical Name[a]	CAS Number[b]
Ethane	
Ethanol	64175
Ethanolamine	141435
Ethyl acetate	141786
Ethyl acetoacetate	141979
Ethyl acrylate	140885
Ethylbenzene	100414
Ethyl bromide	74964
Ethyl chloride (Chloroethane)	75003
Ethyl chloroacetate	105395
Ethyl cyanide	107120
Ethyl ether	60297
Ethyl hexanol (2-)	104767
Ethyl mercaptan	
Ethyl orthoformate	122510
Ethyl oxalate	95921
Ethyl sodium oxalacetate	41892711
Ethylamine	75047
Ethylaniline (n-)	103695
Ethylaniline (o-)	578541
Ethylcellulose	9004573
Ethylcyanoacetate	105566
Ethylene	74851
Ethylene carbonate	96491
Ethylene chlorohydrin	107073
Ethylene dibromide (Dibromoethane)	106934
Ethylene dichloride	107062
Ethylene glycol	107211
Ethylene glycol diacetate	111557
Ethylene glycol dibutyl ether	112481

Chemical Name[a]	CAS Number[b]
Ethylene glycol diethyl ether (1,2-diethoxyethane)	629141
Ethylene glycol dimethyl ether	110714
Ethylene glycol monoacetate	542596
Ethylene glycol monobutyl ether acetate	112072
Ethylene glycol monobutyl ether	111762
Ethylene glycol monoethyl ether acetate	111159
Ethylene glycol monoethyl ether	110805
Ethylene glycol monohexyl ether	112254
Ethylene glycol monomethyl ether acetate	110496
Ethylene glycol monomethyl ether	109864
Ethylene glycol monooctyl ether	002
Ethylene glycol monophenyl ether	122996
Ethylene glycol monopropyl ether	2807309
Ethylene oxide	75218
Ethylenediamine	107153
Ethylenediamine tetraacetic acid	60004
Ethylenimine (Aziridine)	151564
2-Ethylhexanol	104767
Ethylhexanoic acid	
Ethylhexyl acrylate (2-isomer)	103117
2-Ethylhexyl alcohol	104767
(2-Ethylhexyl) amine	104756
Ethylhexyl succinate (2-)	
Ethylmethylbenzene	25550145
6-Ethyl-1,2,3,4-tetrahydro-9,10-antracenedione	15547178
Fluoranthene	206440
Formaldehyde	50000
Formamide	75127
Formic acid	64186

Chemical Name[a]	CAS Number[b]
Fumaric acid	110178
Furfural	98011
Glutaraldehyde	111308
Glyceraldehyde	367475
Glycerol	56815
Glycerol dichlorohydrin	26545737
Glycerol tri(polyoxypropylene)ether	25791962
Glycidol	
Glycine	56406
Glycol ethers	
Glyoxal	107222
Guanidine	
Guanidine nitrate	
n-Heptane	142825
Heptenes	---
Hexachlorobenzene	118741
Hexachlorobutadiene	87683
Hexachlorocyclopentadiene	
Hexachloroethane	67721
Hexadecyl alcohol	36653824
Hexadecyl chloride	---
Hexadiene (1,4-)	592450
Hexamethylenediamine	124094
Hexamethylene diamine adipate	3323533
Hexamethylene glycol	629118
Hexamethylenetetramine	100970
Hexane	110543
Hexanetriol (1,2,6-)	106694
2-Hexenedinitrile	13042029
3-Hexenedinitrile	1119853

Chemical Name[a]	CAS Number[b]
Hexyl alcohol	
Hexylene glycol	
Higher glycols	
Hydrogen cyanide	74908
Hydroquinone	123319
Hydroxyadipaldehyde	141311
Hydroxybenzoic acid (p-)	99967
Iminodiethanol (2,2-)	
Isoamyl alcohol	
Isoamyl chloride (mixed)	
Isoamylene	26760645
Isobutane	75285
Isobutanol	78831
Isobutyl acetate	110190
Isobutyl acrylate	106638
Isobutyl alcohol	
Isobutyl methacrylate	
Isobutyl vinyl ether	
Isobutylene	115117
Isobutyraldehyde	78842
Isobutyric acid	79312
Isodecanol	25339177
Isodecyl alcohol	25339177
Isohexyldecyl alcohol	
Isononyl alcohol	
Isooctyl alcohol	26952216
Isopentane	78784
Isophorone	78591
Isophorone nitrile	0017
Isophthalic acid	121915

Chemical Name[a]	CAS Number[b]
Isoprene	78795
Isopropanol	67630
Isopropyl acetate	108214
Isopropyl chloride	75296
Isopropyl ether	
Isopropylamine	75310
Isopropylphenol	25168063
Ketene	463514
Lactic acid	
Lauryl dimethylamine oxide	
Lead acetate	
Lead phthalate	
Lead subacetate	
Linear alcohols, ethoxylated, mixed	---
Linear alcohols, ethoxylated and sulfated, sodium salt, mixed	---
Linear alcohols, sulfated, sodium salt, mixed	---
Linear alkylbenzene	123013
Linear alkyl sulfonate	---
Magnesium acetate	142723
Maleic acid	110167
Maleic anhydride	108316
Maleic hydrazide	123331
Malic acid	6915157
Manganese acetate	
Melamine	108781
Mercuric acetate	
Mesityl oxide	141797
Metanilic acid	121471

Chemical Name[a]	CAS Number[b]
Methacrylic acid	79414
Methacrylonitrile	126987
Methallyl alcohol	
Methallyl chloride	563473
Methane	
Methanol	67561
Methionine	63683
Methyl acetate	79209
Methyl acetoacetate	105453
Methyl acrylate	96333
Methyl anthranilate	
Methyl bromide (Bromomethane)	74839
Methyl butenols	
Methyl butynol	37365712
Methyl chloride (Chloromethane)	74873
Methyl ethyl ketone (2-butanone)	78933
Methyl formate	107313
Methyl hydrazine	60344
Methyl iodide	74884
Methyl isobutyl carbinol	108112
Methyl isobutyl ketone (Hexone)	108101
Methyl isocyanate	624839
Methyl mercaptan	74931
Methyl methacrylate	80626
Methyl phenyl carbinol	98851
Methyl salicylate	
Methyl tert-butyl ether	1634044
Methylamine	74895
Methylaniline (N-)	100618
ar-Methylbenzenediamine	25376458

Chemical Name[a]	CAS Number[b]
Methylbutanol (2-)	
Methylcyclohexane	108872
Methylcyclohexanol	25639423
Methylcyclohexanone	1331222
Methylene chloride (Dichloromethane)	75092
Methylene dianiline (4,4'-isomer)	101779
Methylene diphenyl diisocyanate (4,4'-) (MDI)	101688
Methylionones (a-)	79696
Methylnaphthalene (1-)	
Methylnaphthalene (2-)	
Methylpentane (2-)	107835
Methylpentynol	77758
1-Methyl-2-pyrrolidone	872504
Methylstyrene (a-)	98839
Methyl-1-pentene (2-)	
Monomethylhydrazine	
Morpholine	
Naphthalene	91203
Naphthalene sulfonic acid (a-)	85472
Naphthalene sulfonic acid (b-)	120183
Naphthenic acids	
Naphthol (a-)	90153
Naphthol (b-)	135193
Naphtholsulfonic acid (1-)	567180
Naphthylamine sulfonic acid (1,4-)	84866
Naphthylamine sulfonic acid (2,1-)	81163
Naphthylamine (1-)	134327
Naphthylamine (2-)	91598
1-Naphthyl-N-methylcarbamate	
Neohexane	

Chemical Name[a]	CAS Number[b]
Neopentanoic acid	75989
Neopentyl glycol	
Nickel formate	
Nitriloacetic acid	
Nitrilotriacetic acid	
Nitroaniline (m-)	99092
Nitroaniline (o-)	88744
Nitroaniline (p-)	100016
Nitroanisole (o-)	91236
Nitroanisole (p-)	100174
Nitrobenzene	98953
Nitrobenzoic acid (m-)	27178832
Nitrobenzoic acid (o-)	27178832
Nitrobenzoic acid (p-)	27178832
Nitrobenzoyl chloride (p-)	
Nitroethane	79243
Nitroguanidine	
Nitromethane	75525
Nitronaphthalene (1-)	86577
Nitrophenol (p-)	100027
Nitrophenol (o-)	88755
Nitropropane (1-)	25322014
Nitropropane (2-)	79469
Nitrotoluene (all isomers)	1321126
Nitrotoluene (o-)	88722
Nitrotoluene (m-)	99081
Nitrotoluene (p-)	99990
Nitroxylene	25168041
Nonene	27215958
Nonyl alcohol	1430808

Chemical Name[a]	CAS Number[b]
Nonylbenzene (branched)	1081772
Nonylphenol	25154523
Nonylphenol (branched)	
Nonylphenol, ethoxylated	9016459
N-Vinyl-2-pyrrolidine	
Octane	
Octene-1	111660
Octylamine (tert-)	
Octylphenol	27193288
Oil-soluble petroleum sulfonate calcium salt	---
Oil-soluble petroleum sulfonate sodium salt	---
Oxalic acid	
Oxamide	
Oxo chemicals	
Paraformaldehyde	30525894
Paraldehyde	123637
Pentachlorophenol	87865
Pentaerythritol	115775
Pentaerythritol tetranitrate	
Pentane	109660
Pentanethiol	115775
Pentanol (2-)	
Pentanol (3-)	
Pentene (1-)	109671
Pentene (2-)	109671
Pentenes, mixed	109671
3-Pentenenitrile	4635874
Peracetic acid	79210
Perchloromethyl mercaptan	594423
Phenacetin	

Chemical Name[a]	CAS Number[b]
Phenanthrene	85018
Phenetidine (o-)	94702
Phenetidine (p-)	156434
Phenol	108952
Phenolphthalein	77098
Phenolsulfonic acids (all isomers)	1333397
Phenyl anthranilic acid (all isomers)	91407
Phenylenediamine (m-)	
Phenylenediamine (o-)	
Phenylenediamine (p-)	106503
1-Phenyl ethyl hydroperoxide	3071327
Phenylmethylpyrazolone	
Phenylpropane	103651
Phloroglucinol	108736
Phosgene	75445
Phthalic acid	88993
Phthalic anhydride	85449
Phthalimide	85416
Phthalonitrile	91156
Picoline (a-)	
Picoline (b-)	108996
Picramic acid	
Picric acid	
Piperazine	110850
Piperidine	
Piperylene	
Polybutenes	9003296, 25036297
Polyethylene glycol	25322683
Polypropylene glycol	25322694

Chemical Name[a]	CAS Number[b]
Potassium acetate	
Propane	74986
n-Propanol	
Propiolactone (beta-)	57578
Propionaldehyde	123386
Propionic acid	79094
Propyl acetate (n-)	
Propyl alcohol (n-)	71238
Propyl chloride	540545
Propylamine	107108
Propylene	115071
Propylene carbonate	108327
Propylene chlorohydrin	127004
Propylene dichloride (1,2-dichloropropane)	78875
Propylene glycol	57556
Propylene glycol monomethyl ether	107982
Propylene oxide	75569
Pseudocumene	
Pseudocumidine	
Pyrene	129000
Pyridine	110861
Pyrrolidone (2-)	
p-tert-Butyl toluene	98511
Quinone	106514
Resorcinol	108463
Salicylic acid	69727
Sebacic acid	
Sodium acetate	127093
Sodium benzoate	532321
Sodium carboxymethyl cellulose	9004324

Chemical Name[a]	CAS Number[b]
Sodium chloroacetate	3926623
Sodium cyanide	143339
Sodium dodecyl benzene sulfonate	
Sodium formate	141537
Sodium methoxide	124414
Sodium oxalate	
Sodium phenate	139026
Sodium propionate	
Sorbic acid	110441
Sorbitol	50704
Stilbene	588590
Styrene	100425
Succinic acid	110156
Succinonitrile	110612
Sulfanilic acid	121573
Sulfolane	126330
Synthesis gas	
Tannic acid	1401554
Tartaric acid	526830
Terephthalic acid	100210
Teraphthaloyl chloride	
Tetrabromophthalic anhydride	632791
Tetrachlorobenzene (1,2,3,5-)	
Tetrachlorobenzene (1,2,4,5-)	95943
Tetrachloroethane (1,1,2,2-)	79345
Tetrachloroethylene (Perchloroethylene)	127184
Tetrachlorophthalic anhydride	117088
Tetraethyl lead	78002
Tetraethylene glycol	112607
Tetraethylenepentamine	112572

Chemical Name[a]	CAS Number[b]
Tetrafluoroethylene	
Tetrahydrofuran	109999
Tetrahydronapthalene	119642
Tetrahydrophthalic anhydride	85438
Tetramethylenediamine	110601
Tetra (methyl-ethyl) lead	---
Tetramethylethylenediamine	110189
Tetramethyllead	75741
Thiocarbanilide	102089
Thiourea	
Tolidines	
Toluene	108883
Toluene 2,4 diamine	95807
Toluene 2,4 diisocyanate	584849
Toluene diisocyanates (mixture)	26471625
Toluene sulfonamides (o- and p-)	1333079
Toluene sulfonic acids	104154
Toluenesulfonyl chloride	98599
Toluidine (o-)	95534
Tribromomethane	75252
Trichloroacetic acid	
Trichloroaniline (2,4,6-)	634935
Trichlorobenzene (1,2,3-)	87616
Trichlorobenzene (1,2,4-)	120821
Trichlorobenzene (1,3,5-)	108703
Trichloroethane (1,1,1-)	71556
Trichloroethane (1,1,2-) (Vinyl trichloride)	79005
Trichloroethylene	79016
Trichlorofluoromethane	75694
Trichlorophenol (2,4,5-)	95954

Chemical Name[a]	CAS Number[b]
Trichloropropane (1,2,3-)	96184
(1,1,2-) Trichloro (1,2,2-) trifluoroethane	76131
Tricresyl phosphate	
Tridecyl alcohol	
Tridecyl mercaptan	
Triethanolamine	102716
Triethylamine	121448
Triethylene glycol	112276
Triethylene glycol dimethyl ether	112492
Triethylene glycol monoethyl ether	112505
Triethylene glycol monomethyl ether	112356
Triisobutylene	7756947
Trimellitic anhydride	
Trimethyl pentanol	
Trimethylamine	75503
Trimethylcyclohexanol	933482
Trimethylcyclohexanone	2408379
Trimethylcyclohexylamine	34216347
Trimethylolpropane	77996
Trimethylpentane (2,2,4-)	540841
Trimethyl-1,3-pentanediol (2,2,4-)	
Tripropylene glycol	24800440
Urea	57136
Vinyl acetate	108054
Vinyl chloride (Chloroethylene)	75014
Vinyl toluene	25013154
Vinylcyclohexene (4-)	100403
Vinylidene chloride (1,1-dichloroethylene)	75354
Vinyl(N-)-pyrrolidone(2-)	88120
Vinylpyridine	

Chemical Name[a]	CAS Number[b]
Xanthates	140896
Xylene sulfonic acid	25321419
Xylenes (NOS)[c]	1330207
Xylene (m-)	108383
Xylene (o-)	95476
Xylene (p-)	106423
Xylenols (Mixed)	1300716
Xylenol (2,3-)	1300716
Xylenol (2,4-)	1300716
Xylenol (2,5-)	1300716
Xylenol (2,6-)	1300716
Xylenol (3,4-)	1300716
Xylenol (3,5-)	1300716
Xylidene	1300738
Xylidene (2,3-)	1300738
Xylidene (2,4-)	1300738
Xylidene (2,5-)	1300738
Xylidene (2,6-)	1300738
Xylidene (3,4-)	1300738
Xylidene (3,5-)	1300738
Zinc acetate	

[a]Isomer means all structural arrangements for the same number of atoms of each element and does not mean salts, esters, or derivatives.

[b]CAS Number = Chemical Abstract Service number.

[c]NOS = not otherwise specified.